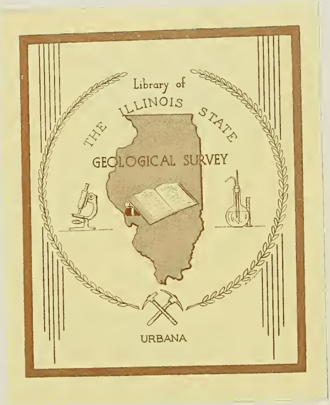

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GEOLOGY

MAJOR AQUIFERS IN GLACIAL DRIFT NEAR MATTOON, ILLINOIS*

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Subsurface Pleistocene studies near Mattoon recently conducted by the Illinois State Geological Survey have revealed the probable origin and nature of occurrence of two gravel aquifers of major importance. The report describes a veneer of sand and gravel which rests on the Sangamon interglacial surface over a wide area north of the Shelbyville moraine which here marks the maximum stage of Wisconsin glaciation. A second, more restricted but more favorable aquifer of Shelbyville age lies immediately south of the Shelbyville terminus and extends from the ground surface to the top of Illinoian drift. The relationships of these gravel aquifers to the Cerro Gordo and Shelbyville moraines, to the undulations of the Sangamon surface, and to the topography of the top of the bedrock are described. The investigation is expected to lead to the discovery of unknown aquifer deposits of similar genesis in areas of similar geologic conditions.

Introduction. — Geological and geophysical studies of the gravel aquifers near Mattoon have been conducted by the State Geological Survey at intermittent periods for many years. The older surveys have been directed principally toward the location of the areas most favorable for well field construction. The present investigation, largely a subsurface study by the records of 114 drift borings, has been designed toward not only descriptive geology but an insight into the physical development of the Mattoon aquifers. It is hoped that this insight will lead toward a better understanding of the groundwater available to Mattoon, its industries and hinterland farms, and lead also toward the discovery of other still unknown aquifer deposits of similar rank lying in areas of similar Pleistocene history.

General setting.—The one hundred and ninety-two square miles of the Mattoon investigation lie entirely in southwestern Coles county and include Townships 12 and 13 north, Ranges 7 and 8 east, and the north four section tiers of Township 11 north, Range 7 and 8 east. The terrain is largely rolling to nearly level upland prairie, shedding drainage west into the Kaskaskia, south into the Little Wabash, and east into the Embarrass systems. Relief is only 165 feet, with elevations ranging from about 620 feet on the Kaskaskia River in the northwest area and the Little Wabash River in the southwest area to about 785 feet on the highest crest of the Shelbyville moraine (fig. 2) near the southwest

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corner of T.12 N., R.8 E. Mattoon, with a population estimated at more than 18,000, lies on the gentle north or backslope of the Shelbyville moraine in the south-central area.

As in most of east-central Illinois, the glacial drift near Mattoon rests on the shales, thin limestones, sandstones, and coals of the Pennsylvanian system. Bedrock here is exposed at very restricted locations along the Kaskaskia valley north of the Cerro Gordo moraine (figs. 2 and 3). Everywhere else drift, with estimated thicknesses up to approximately 220 feet in southwestern T.12 N., R. 7 E., buries the bedrock surface and completely obscures its topography. Drift of Illinoian age is capped with younger Wisconsin deposits associated with the Shelbyville and Cerro Gordo ice lobes (Leighton, Ekblaw, Horberg, 1948, p. 22) of Tazewell age. Each of these drift mantles shows surface expression, the Illinoian as a nearly level till plain beyond the influence of Wisconsin ice, the Shelbyville as a prominent moraine, and the Cerro Gordo as a more gentle moraine and till plain in the far north portion of the Mattoon area.

The bedrock surface.—The buried bedrock surface of the Mattoon area is principally interfluve between the pre-glacial Embarrass (Horberg, 1950, p. 84) and Middletown (Horberg, 1950, p. 73) drainage systems. The shallow sags in the bedrock topography in the northeast portion of the area were apparently courses tributary to the great Embarrass bedrock valley which trends southerly in the eastern part of Coles County. The more prominent bedrock valleys of the Mattoon area appear to trend westward and northwestward as part of the buried Middletown valley which in turn is in confluence with the ancient course of the Mississippi River in eastern Mason County. Although Illinoian drift to a great degree obscured the subdued topography of the top of the bedrock, the southernmost of the west-trending bedrock valleys appears to have influenced the building of a Wisconsin gravel aquifer, and probably influences the hydrologic characteristics of that aquifer.

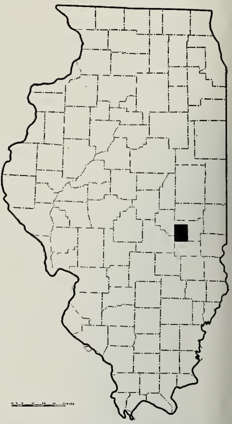

FIG. 1.—Index map showing location of the area of investigation near Mattoon, Illinois.

Illinoian drift.—For the most part the bedrock near Mattoon is mantled

Fig. 2.—Surface contour and moraine configuration map.

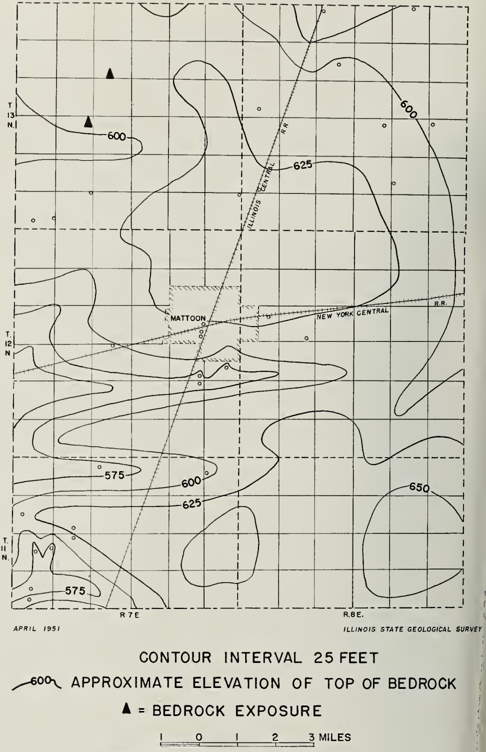

Fig. 3.—Buried bedrock surface contour map.

with Illinoian drift. Two exceptions are noted: (1) Reliable samples from a 1944 Mattoon City test hole located NE. SE. NE. sec. 18, T.11 N., R. 7 E., indicate that the basal material is a fine to coarse silty sand with an abundance of humus and most likely represents a Yarmouth interglacial alluvial deposit. No convincing evidence of Kansan drift has been noted in this subsurface investigation. (2) Three borings in T.11 N., R. 7 E., penetrated to the bedrock without apparently cutting pre-Wisconsin material. These suggest that Sangamon erosion denuded the bedrock at numerous though probably restricted locations principally along Sangamon drainage systems and in localities where Illinoian drift was originally thin. Inasmuch as the top of Illinoian drift appears to have been a gently undulating plain, at an average elevation of about 625 feet, the greater Illinoian drift thicknesses occur generally over the depressions of the bedrock surface. The greatest Illinoian drift thickness in the Mattoon area is estimated to be about 90 feet where a low bedrock surface is overlain by a relatively high Sangamon surface in sec. 19, T.12 N., R.8 E.

Illinoian drift over wide areas here is exclusively a grey or grey-green calcareous clay till which lacks the sandy character typical of Illinoian drift in most of Champaign County. The upper 5 to 10 feet of Illinoian till shows clearly by representative samples the weathering during the Sangamon interglacial period. The general textural homogeneity of the Illinoian drift lends no support to the possibility of multiple Illinoian glaciation, although this fact by no means precludes such a history.

Aquifer material in Illinoian drift, though very uncommon near Mattoon, may be extremely important in its influence on the hydrology of Wisconsin gravels immediately south of the Shelbyville moraine. In sec. 18, T.11 N., R.7 E., pre-Wisconsin sand deposits are as thick as 45 feet and occupy there a well-developed valley of the bedrock surface, drift boring number 4, fig. 4. The nature of this pre-Wisconsin sand is unknown, but the deposit is very likely restricted to the bedrock valley in which it lies, and probably trends westward in conformity with the valley configuration. Samples from boring number 4 suggest that this sand is silty to very silty and may not in itself be an important direct source of groundwater.

Sangamon soil.—Well drillers in the Mattoon area are familiar with the ''peat'' which rests largely on Illinoian till. It is this remarkably preserved soil section that has provided an excellent horizon marker here.

The excellence of the Sangamon interglacial soil development as a marker near Mattoon has enabled the use of driller's logs where they might otherwise be of little value in geological Pleistocene interpretation. Unusual preservation of Sangamon loam here through the overrunning of the later Wisconsin glacier is probably due to the equally unusual nature of the advance of the Shelbyville ice.

Shelbyville ice progression and the spreading of gravel veneer.—The progression of Shelbyville ice into the Mattoon area early in Tazewell

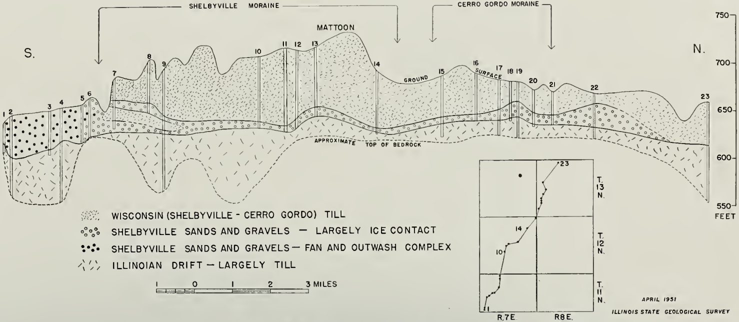

Fig. 4.—South-north cross section of the glacial drift, showing the relationships of the aquifer deposits to each other and to older and younger tills.

time, with a southwesterly lobate axis, began the key period of aquifer building. Subsurface data throughout the area show that a widespread veneer of gravel and sand was laid directly on the Sangamon soil by strong pro-glacial fluvial activity. Figure 4 illustrates the persistence with which these coarse Shelbyville clastics were spread, apparently without much regard for the hills and dales of the Illinoian (or Sangamon) surface. The adaptability of the gravel veneer to the topography indicates that the veneer was spread either subglacially under hydrostatic pressure or as ice-contact accumulation along the advancing zone of strong periglacial fluvial activity. Deposits of outwash origin distant from the glacier mass would concentrate in the existing sags of the Illinoian drift surface with very thin deposition, if any, on the topographic highs. The wide occurrence of the gravel veneer here apparently eliminates the possibility of subglacial origin, leaving the likelihood of ice-contact origin.

Fan and outwash complex.—Shelbyville ice appears to have reached the north portion of T.11 N., R.7 E., about 5 miles south of the present city of Mattoon, without great mechanical change. Here, however, ice-front progression ceased and deterioration of the front probably paced the movement of ice into the terminus area. During this part of the Shelbyville time began the building of a complex fan and outwash deposit immediately south of the glacier terminus near secs. 17, 18, 19, and 20, T.11 N., R.7 E., south of the present Lake Mattoon. Sands of this complex accumulated first in the sag in the Illinoian drift surface (which is apparently the reflection of a partially obscured bedrock valley).

The present valley of the Little Wabash River cuts deeply into the Shelbyville moraine (fig. 2) directly behind the Shelbyville fan and outwash complex and may represent the course of a subglacial or superglacial torrent from which a portion of the complex would have been derived. Periglacial deposits here originating from an ice-fed torrent would likely have spread as an alluvial fan close to the stream's emergence from the ice mass. Such fan-type gravels would combine with earlier and later outwash gravels to form an aquifer deposit similar to the complex found in secs. 17, 18, 19, and 20, T.11 N., R.7 E.

Borings 7, 8 and 9 of fig. 4 show the occurrence of a till bed five to ten feet in thickness intercalated between gravels near the south edge of the Shelbyville moraine. This till zone may have been the result of a minor northward retreat of the ice front a distance of about two miles. The momentary ice front control by ablation may then have been lost by reinvasion to a position nearly equal to the former Shelbyville terminus, spreading as it progressed a second gravel veneer, shown on fig. 4.

The second invasion renewed the building of the fan and outwash complex beyond the limit of Wisconsin glaciation. Subsequent till deposition resulted in the prominent Shelbyville moraine which is the landmark of the Mattoon region. Fluvial deposits of sand and gravel associated with the final recessional stage of the Shelbyville ice front are very rare or absent within the till near Mattoon. Although the extent of the final retreat of the Shelbyville ice front is not known, ice of this stage of Tazewell glaciation must have ablated at least 50 miles, as Shelbyville drift in central Champaign County exhibits a young soil profile, but little or no leaching.

Cerro Gordo lobate ice. — Post-Shelbyville glaciation in the Mattoon area is believed to include only the development of the more restricted Cerro Gordo lobe, with an axis similar in direction to that of the earlier Shelbyville lobe. Perhaps, because of meager fluvial activity or because of lack of coarse clastic load, the Cerro Gordo glacier failed to spread before it the gravel veneer which Shelbyville ice spread with such uniformity. Drilling above the Shelbyville drift in and north of the Cerro Gordo moraine has revealed no more than widely scattered thin sands of limited groundwater resources. Cerro Gordo ice near Mattoon reached its maximum in extreme northern T.12 N., R.7 and 8 E., about one mile north of the city (fig. 2). The till sheet deposited by the Cerro Gordo ice rests on older Shelbyville till. The horizon between the two tills should be recognizable from sample study on the basis of weathering on the top of the buried Shelbyville till and on the basis of pre-Cerro Gordo soil development. The subsurface distinction of the Cerro Gordo and Shelbyville tills, however, has not been made in the area of this investigation for lack of suitable sample cuttings in the key area of Cerro Gordo overlap. Illinois State Geological Survey files contain sample study records which show that pre-Cerro Gordo soil has been identified at many well sites in Douglas and Champaign counties, north of the Mattoon area.

Geo-hydrology of the aquifers.— Despite the uniformity of thickness of the Shelbyville gravel veneer north of the Shelbyville moraine, the textural composition of the aquifer shows great variation from place to place. The veneer exhibits over wide areas a three- to ten-foot bed of very fine sand at the base of the aquifer, directly above Sangamon soil. Where this fine sand composes the entire thickness of the Shelbyville veneer, well construction even for domestic groundwater is difficult. Borings in the veneer not restricted to any given locality commonly exhibit a bed of clean, very coarse gravel with a thickness up to fifteen feet intercalated between beds of less well sorted silty sand and gravel. It is the very coarse gravel deposit which yields abundant groundwater at scattered sites through the Mattoon area, although even the poorly sorted sand and gravel, where the coarse material is missing, yields more than adequate domestic groundwater supplies.

Far more favorable than the gravel veneer north of the Shelbyville moraine is the gravel aquifer of the fan and outwash complex in the area of secs. 17, 18, 19, and 20, T.11 N., R.7 E., largely south of the limit of Wisconsin glaciation. The veneer and the complex gravel formations are distinct both geologically and by hydrologic characteristics and are being considered here as two aquifers. The fan and outwash complex has a number of geologic features which encourage favorable groundwater yields:

(1.) The sand and gravel complex of Shelbyville age extends from the ground surface to the top of the Illinoian drift with thicknesses up to 65 feet. These thicknesses are due to the well-defined sag in the Illinoian drift surface previously described. No such thicknesses of gravel are known in the Shelbyville veneer to the north.

(2.) The fan and outwash complex in a number of test holes in T.11 N., R.7 E., has two or more zones of clean, very coarse gravel with combined thicknesses of twenty feet or more.

(3.) The complex is in hydrologic contact with the buried Shelbyville gravel veneer on the north, thereby facilitating groundwater recharge.

The complex is probably also in hydrologic contact with Illinoian gravels occupying the bedrock valley which directly underlies part of the complex area. Borings here have encountered an upper Illinoian till deposit which, if continuous, might effectively seal the deep gravels from recharge of the shallower gravel complex. Where erosion of the upper Illinoian till may have exposed deep Illinoian gravels during Sangamon time, Illinoian and Wisconsin gravels may be in direct contact. Inasmuch as the deeper Illinoian gravels are believed to be generally silty and limited in permeability, wells in the complex area will probably be constructed in the clean Shelbyville gravels, even though these are relatively shallow and widely exposed.

City of Mattoon well field construction.—Mattoon wells are concentrated in two areas, the Dorans field near sec. 30, T.12 N., R.8 E., and the Southwest field near sec. 18, T.11 N., R.7 E. City wells constructed prior to 1944 were located largely in the Dorans area. These penetrate to depths of 40 to 70 feet and tap groundwater in the Shelbyville gravel veneer. The Dorans wells have never shown capacities adequate for the demands of a city the size of Mattoon. By 1935 Lake Mattoon was supplying the city with the major portion of its water needs. Limited surface inflow in the summer of 1944, caused by rainfall deficiencies recorded by the United States Weather Bureau in the months of May, June, and July of that year, lowered surface storage to an alarming level. Geophysical exploration was conducted by the State Geological Survey for the purpose of discovering, if possible, groundwater aquifers more prolific than that at the old Dorans field. Electrical earth resistivity exploration delineated in 1944 the very favorable gravels in the area of secs. 17, 18, 19, and 20, T.11 N., R.9 E., described in this study as the Shelbyville fan and outwash complex.

Lake Mattoon still furnishes the major portion of water requirements at Mattoon though limited pumping of the Dorans well field continues. However, the construction of wells in the Southwest area, since 1944, which penetrate the most prolific deposit near Mattoon, safeguards the city's supplies against future low water levels of Lake Mattoon. Furthermore, industries which can locate in the vicinity of the Shelbyville fan and outwash complex will be assured of a source of abundant groundwater available for independent development. This favorable situation exists at very few industrial sites in this region.

Acknowledgment. — The author gratefully recognizes the many contributors to the present concepts of Illinois Pleistocene upon whose groundwork this investigation has been made. The author is indebted to M. M. Leighton, Chief, and George E. Ekblaw, Head of Engineering Geology and Topographic Mapping Division, of the Illinois State Geological Survey, for helpful comments during the assembling and interpretation of data.

REFERENCES

Horberg, C. L. (1950), Bedrock Topography of Illinois: Illinois State Geological Survey Bull. 73, p. 73.

Horberg, C. L. idem. p. 84.

Leighton, M. M., Ekblaw, George E., and Horberg, C. L. (1948), Physiographic Divisions of Illinois, Jour. Geol., vol. 56, no. 1, p. 22.

NOTES ON THE ILLINOIS "LAFAYETTE" GRAVEL*

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Extreme southern Illinois contains many exposures of brown chert gravel and red sand which are loosely referred to as the "Lafayette" formation of Tertiary age. Deposits of Lafayette-type gravel occur in other parts of Illinois but are mostly thin.[1] One of the northernmost sizable deposits in Illinois which closely resembles the southern Illinois gravels is found near Hamilton in Hancock County, about 250 miles northwest of the main body of "Lafayette" sediments in southern Illinois.

The "Lafayette" gravel is commonly regarded as stream deposited. The drainage patterns that must have been involved in most of this deposition have not been established, nor is it possible to say to what extent the gravels may have been reworked. Solution of these problems will involve, among other things, a study of the sedimentology and lithology of many samples carefully taken with regard to their topographic occurrence and elevation. The preliminary work here described was undertaken to obtain better knowledge of some of the physical characteristics of the Lafayette gravel which might be important to broader investigations.

SAMPLES

The six samples used in this investigation were taken from the following exposures (fig. 1):

FIG. 1.—Locations of deposits sampled and of other outcrops of "Lafayette" gravel as reported by Horberg, Leland, Preglacial gravels in Henry Co., Illinois, Trans. Ill. Acad. Sci., vol. 43, p. 172, 1950.

Sample No. 1. SE¼ SW¼ sec. 6, T. 4 N., R. 3 W., near Hamilton, Ill., 10 feet of gravel in gravel pit. Elevation about 620 feet.

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[1] Horberg, Leland, Pre-glacial erosion surfaces in Illinois: Jour. Geol., Vol. LIV, No. 3, 1946, p. 184.

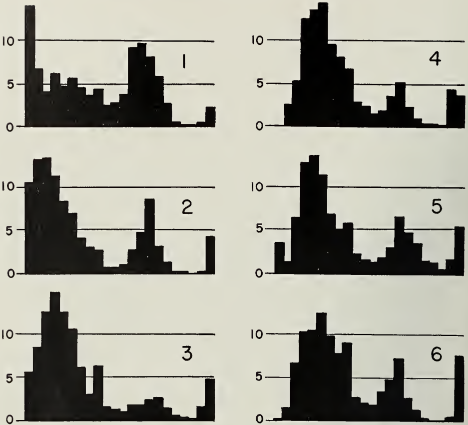

Fig. 2.—Particle-size histograms. The vertical bars, reading from left to right, indicate percent retained on the following sieves: 2″, 1.5″, 1.05″, .742″, .525″, .371″, 3 mesh, 4, 8, 10, 14, 20, 28, 35, 48, 65, 100, 150, 200, and 270 mesh; passing 270 mesh plus 2 microns, and minus 2 microns.

Sample No. 2. NE¼ SE¼ sec. 4, T. 44 N., R. 3 E., near Grover, Mo., 30 feet of gravel. This deposit is not far from Calhoun County, Ill., and was sampled instead of Calhoun County deposits because the exposure was better and the thickness of the gravel greater. Elevation about 820 feet.

Sample No. 3. SW¼ NE¼ sec. 34, T. 15 S., R. 3 W. near Fayville, Ill., 10 feet of gravel in small gravel pit. Elevation about 400 feet.

Sample No. 4. NE¼ SW¼ sec. 15, T. 16 S., R. 1 W. near Mounds, Ill., 3½ feet of gravel in road cut. Elevation about 400 feet.

Sample No. 5. SW¼ SW¼ SE¼ sec. 29, T. 14 S., R. 2 E. near Grand Chain, Ill., 8 feet of gravel in railroad cut. Elevation about 430 feet.

Sample No. 6. SW¼ SW¼ sec. 28, T. 14 S., R. 5 E. near Renshaw, Ill., 20 feet of gravel in road cut. Elevation about 520 feet.

Mechanical Analyses

Mechanical analyses of the six samples were made by standard procedures. Results are shown in figure

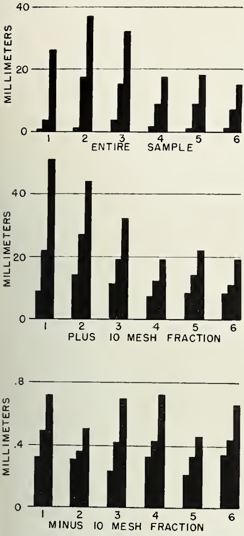

Fig. 3.—Histograms showing first quartile (left-hand bar), median (center bar) and third quartile (right-hand bar) of "Lafayette" gravel samples.

2. All the charts are bimodal. Those for samples 2, 3, 4, 5, and 6 are roughly similar. The curve for sample 1, however, differs in the shape and amplitude of its sand fraction peak and in the particle size distribution of the gravel fraction.

In figure 3 are shown certain statistical values determined from the particle size analyses. The quartile and median data for the samples as a whole indicate that samples 2 and 3 are the coarsest and sample 6 is the finest. In the plus 10 mesh fraction, sample 1 is the coarsest and samples 4 and 6 the finest. In general a kinship is suggested between samples 1, 2, and 3 from Hamilton, Grover, and Fayville, respectively, and between samples 4, 5, and 6.

Pebble Counts

In order to determine the lithology of the "Lafayette" gravel, pebble counts were made on 100 pebbles selected at random from each of four size fractions of each sample. All chert pebbles were classified according to color: brown, light buff, red, and black. The size fractions counted and the results of the counts are shown in figure 4.

The following characteristics are indicated for each of the size fractions:

1.05 x .742″	Samples 1, 2, and 3 contain black and red chert and sample 2 is relatively high in light brown chert.
.742 x .525″	Sample 1 differs from the other samples in having a high content of red chert and vein quartz. Samples 1, 2, and 4 contained more light brown chert than the other samples.
.525 x .371″	Sample 1 differs from the other samples in having a high content of vein quartz and of buff chert pebbles.
.371 x .19″	Samples 1 and 3 are high in vein quartz pebbles. Sample 2 is high in light brown chert pebbles and Sample 4 is high in red chert.
1.05 x .19″	Sample 1 is unlike all others because of its

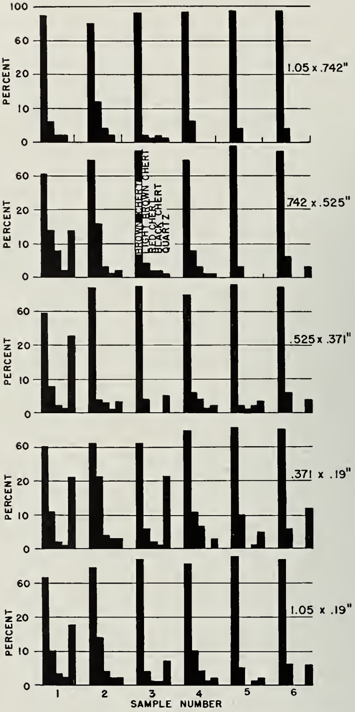

Fig. 4.—Results of pebble counts in percent by number of pebbles. Percent scale changes at 20 percent.

low chert content and high compensating vein quartz content. Samples 1, 2, and 4 contain the most light brown chert pebbles and also the most red chert pebbles.

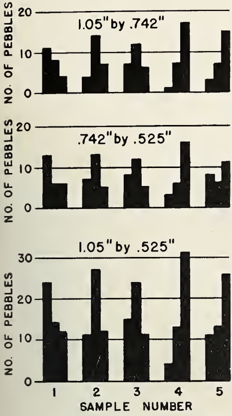

Fig. 5.—Degree of polish of pebbles. Left-hand bar indicates number of pebbles having "good" polish, center bar "fair" polish, and right-hand bar "poor" polish.

To summarize the foregoing, sample 1 differs from all other samples in its high vein quartz content. Samples 1 and 2 are akin in several respects, as are samples 5 and 6. Samples 3 and 4 are of intermediate character. This is probably to be expected because samples 1 and 2 are from the Mississippi Valley and samples 5 and 6 from the Ohio Valley, whereas samples 3 and 4, near the junction of the two valleys, show affiliations with both valleys. The Mississippi Valley gravel samples commonly differ from the Ohio Valley gravel in the following ways: they contain more vein quartz, light brown chert, red chert, and black chert pebbles. The Ohio Valley samples are characterized by a high content of brown chert pebbles.

Conclusions regarding the lithology of pebbles counted in relation to size are shown in table 1.

Table 1.—Prevalence of Pebbles by Kind

Kind of pebble	Prevalence	
	Greatest	Least
Brown chert	1.05 x .742 inches	.371 x .19 inches
Light brown chert	.371 x .19	.525 x .371
Red chert	.742 x .525 and .371 x .19	.525 x .371
Black chert	About the same in	all sizes
Vein quartz	.371 x .19	1.05 x .742

Table 2.—Shape of Pebbles
(In percent by numbers of pebbles)

Sample No.	1.05″ x .742″ fraction				.742″ x .525″ fraction				1.05″ x .525″ fraction			
	I*	II	III	IV	I	II	III	IV	I	II	III	IV
1	64	16	4	16	64	24	12	0	64	19	8	9
2	32	40	12	16	28	24	32	16	30	33	21	16
3	32	36	12	20	44	16	20	20	37	27	16	20
4	32	16	16	36	60	20	12	8	47	18	14	21
5	52	28	4	16	56	12	16	16	54	20	10	16
6	36	24	8	32	40	28	8	24	38	26	8	28
2 (quartz)	39	55	0	6	37	47	0	16	38	52	0	10
3 (quartz)	....	....	......	....	38	30	16	16	....	....	......	....

* I—Flattened or disc shaped.
II—Spheres or equidimensional pebbles.
III—Bladed or lath-like.
IV—Rod shaped.

These data carry various implications regarding source deposits. The black chert, and to a lesser extent the red chert, appears to have come from deposits having a uniform particle size distribution. In contrast the vein quartz pebbles came from a source that yielded pebbles mostly smaller than ½ inch.

In addition to the kinds of pebbles mentioned, there were observed in the gravel samples, in amounts probably less than one percent, other kinds of pebbles that may prove valuable in determining the source of the gravel. These were quartzite, agate, and jasper pebbles. No igneous rock pebbles were observed, nor have they been seen in Illinois outcrops.

Shape

Shape studies were made on two sizes of chert pebbles, namely, 1.05″ x .742″ and .742″ x .525″. Pebbles of these sizes were selected because they are common and easily handled. In addition, the shapes of 25 quartz pebbles from samples 2 and 3 were measured to provide comparative data.

Standard methods[2] were employed in measuring the pebbles. Shape designations were assigned by the Zingg shape classification[3], which provides for four classes. These are indicated in table 2 together with results of the shape studies.

Table 3.—Average Sphericity Values

Sample No.	Size of pebbles	
	1.05″ by .742″	.742″ by .525″
1	.70	.69
2	.72	.67
3	.70	.66
4	.65	.67
5	.65	.68
6	.70	.69

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[2] Krumbein, W. C., Measurement and geological significance of shape and roundness, Jour. Sed. Petr. vol. 11, no. 2, Aug. 1941, p. 66.

[3] Krumbein, W. C., *op cit.*, p. 67.

The results indicate a similarity of shape between pebbles in samples 2 and 3 in the 1.05 x .742 inch fraction and a less striking similarity between samples 3 and 5 in the .742 x .525 inch fraction. Considering both fractions together there is a likeness between samples 4 and 5. The shape data do not, therefore, show any consistent relationship between the samples.

Flattened or disc-shaped pebbles are most common; they comprise 45 percent of the six samples investigated. Twenty-four percent of the pebbles are spherical or equidimensional, 13 percent bladed or lath-like, and 18 percent rod shaped.

Shape determination on two sizes of quartz pebbles from sample 2 and one size from sample 3 yielded differing results (table 2), but show a dominance of flattened or disc-shaped and spherical or equidimensional pebbles. Sample 2 contains no bladed or lath-like pebbles.

SPHERICITY

Sphericity was determined directly from a modification of the Zingg diagram.[4] Table 3 gives the sphericity data. No distinctive differences are apparent between samples.

ROUNDNESS

The roundness of the pebbles previously measured for shape was determined by comparing them with Krumbein's visual roundness chart.[5] The results are given in table 4; also comparable measurements of 25 vein quartz pebbles from samples 2 and 3. The chert pebbles of sample 1 are the least round. The other samples show no outstanding differences. The quartz pebbles are more round than the chert pebbles.

The roundness values of the chert pebbles commonly result from a rounding of the edges and corners of the pebbles rather than major alteration of the general pebble shape. Well-rounded chert pebbles are infrequent in the sizes studied; such pebbles as are found may have come from a distant source, although some of them may have had a high initial roundness.

TABLE 4.—AVERAGE ROUNDNESS VALUES

Sample No.	Size of pebbles	
	1.05″ by .742″	.742″ by .525″
1—chert pebbles...	.44	.40
2 ″ ″	.50	.48
3 ″ ″	.48	.46
4 ″ ″	.48	.48
5 ″ ″	.50	.51
6 ″ ″	.52	.48
2—quartz pebbles..	...	.73
3 ″ ″	...	.73

Since the quartz pebbles are more rounded than the chert pebbles, and also are probably more resistant to abrasion, it seems likely that they may have attained much of their present degree of rounding in a pre-"Lafayette" cycle of erosion. Conceivably most of them found in the "Lafayette" gravel in southern Illinois may have been derived from the Caseyville (Pennsylvanian) conglomeratic sandstones which form prominent escarpments a few tens

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[4] KRUMBEIN, W. C., *op. cit.* p. 68.
[5] KRUMBEIN, W. C., *op. cit.* p. 68.

of miles north of the gravel area. This is suggested by the appearance of the pebbles and by a petrographic and sedimentologic study made of them by Reynolds.[6] The source of the quartz pebbles in the Grover and Hamilton samples is a problem for further study.

Polish

An outstanding characteristic of most "Lafayette" gravel deposits of Illinois is the polish shown by the pebbles. Some pebbles are completely or almost completely polished; others have rough corners and edges, with polish on only the larger flat or nearly flat surfaces; still others show polish only in re-entrants in the pebbles. The variations in the extent of the polish may be a function of the amount of wear to which a pebble has been subjected since the original development of the polish.

Fig. 6.—Polished section of a brown "Lafayette" chert pebble. The marginal, brown-stained zone which gives the pebble its exterior color is evident except at the broken upper left corner. An area of brown discoloration produced by the infiltration of iron oxide along incipient fractures is shown by the dark-grey area at the left of the picture. Reflected light. X 7.

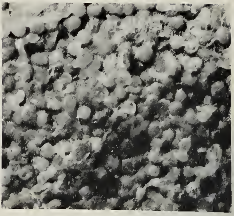

Fig. 7.—The natural surface of one side of a chert pebble which is silicified oolite. It suggests the surface of a freshly broken oolitic limestone. X 4.

The pebbles of sample 6, which have dull, lusterless surfaces, are an exception. The sampled deposit was partly cemented, and the pebbles were coated with a film of limonite. Attempted removal of the limonitic coating by rubbing resulted in a moderate degree of polish, but this may have been caused by the rubbing. Solution of the limonitic film by hydrochloric acid revealed a dull unpolished surface on most pebbles, but in the re-entrants of a few pebbles some polish was evident. This suggests that the gravel of sample 6 was once normally polished. Its loss of polish could be attributed to processes related to cementation; however, as the deposit from which sample 1 was obtained was also part-

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[6] Reynolds, Robert R. A comparative study of the quartz pebbles in the Lafayette gravel and the Caseyville conglomerate of southern Illinois. Masters thesis, Dept. of Geology, Univ. of Illinois, 1942. Unpublished.

ly cemented, though less so than sample 6, and yet contained many highly polished pebbles, cementation cannot be regarded as always adversely affecting polish.

It was evident from an examination of 300 pebbles that in general most of the chert pebbles in the ''Lafayette'' gravel have a higher degree of polish than the other pebbles. The vein quartz pebbles and the few quartzites as a rule have only a fair degree of polish.

In an attempt to determine variations in degree of polish between samples, the chert pebbles whose shapes were measured were arbitrarily classified according to whether their polish was deemed good, fair, or poor. The results are shown in figure 5. Sample 1 from Hamilton, Ill., has the highest degree of polish. Samples 2 and 3 have a moderate degree of polish, whereas samples 4 and 5 are the least well polished. The data at hand are not sufficient to permit an interpretation of these observations, but it is suggested that they probably relate to the history of the pebbles after polishing and perhaps to the varying susceptibilities of different varieties of chert to polishing.

The means by which the ''Lafayette'' pebbles received their polish were not investigated. However, the dense surfaces of some of the porous chert pebbles and of some of the infrequent sandstone pebbles observed suggest that they may have been impregnated with silica.

The brown color and polish of the ''Lafayette'' chert pebbles may be in some way related. Thin sections of chert pebbles show that, although the interiors of the pebbles may be buff, the characteristic brown is commonly restricted to a relatively thin zone at the surface and to bands or streaks along cracks and fractures in the pebble (fig. 6). Twelve pebbles from sample 1 were boiled in hydrochloric acid. Six lost their dark-brown color and changed to an orange brown or yellow brown with cream-colored blotches. Three pebbles became light buff to cream. Three others were little changed. It is noteworthy that though there was a marked color change, the polish of the pebbles was not appreciably altered; the gloss may have been increased, thus suggesting that the polish is not necessarily now linked with the brown color. This inference is further suggested by the fact that the ''glazed'' pebbles, subsequently described, though white or cream colored, are also polished. It seems possible, therefore, that the polish of some pebbles is unrelated to color.

Oolitic Pebbles

A considerable number of the pebbles in the samples studied are silicified oolite. The abundance of oolitic pebbles in the 50 pebbles studied for shape is shown in table 5. Some of the pebbles are obviously chert; others appear to be more coarsely crystalline quartz, although they may be varieties of chert. Many show pitted surfaces, but oolitic pebbles without pits are also common. Numerous coarser-grained pebbles have on their flat or rounded surfaces an intricate pattern composed of roughly crescentic indentations somewhat akin to chattermarks but not regularly distributed. These markings also occur on pebbles which contain fossil detritus but only

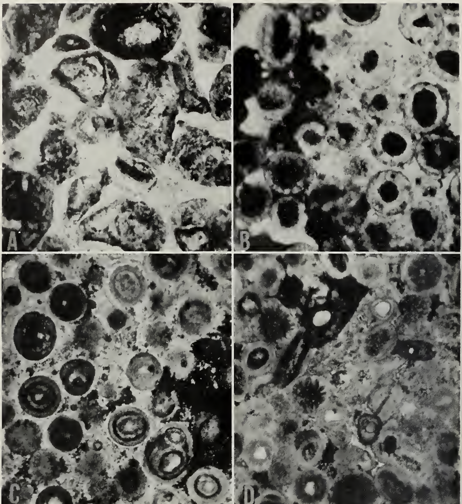

Fig. 8.—Thin sections of silicified "Lafayette" pebbles. A. Originally probably a limestone composed of calcareous detritus and possibly some oolite grains. B. Oolite showing radial structure but little annular banding in grains; grains have dark centers. C. and D. Oolite showing well-developed annular and radial structure; the white centers are macrocrystalline quartz. X 18.

scattered oolite grains. Many of the oolitic pebbles showing the markings are maroon colored. A few oolitic chert pebbles have one natural surface that resembles a freshly broken piece of oolitic limestone. On these surfaces the oolite grains resemble rounded sand grains, and the pebbles might be described as sandstone from casual examination (fig. 7).

The oolitic pebbles are diverse (fig. 8). Some consist largely of roughly spherical oolite grains, generally showing an annular structure; others are composed of numerous annular oolite grains, together with an abundance of granular material, probably detrital, which does not show notable concentric structure or spherical shape. Small fossils

TABLE 5.—NUMBER OF OOLITIC PEBBLES IN PERCENT BY NUMBER OF PEBBLES

Sample No.	.742″ x 1.05″	.525″ x .742″	.525″ x 1.05″
1	4	6	5
2	10	10	10
3	8	4	6
4	12	14	13
5	6	4	5
6	0	0	0

such as brachiopods and fragments of large fossils are common in some pebbles. The grain size of the oolites and other materials is variable, as is the ease with which the textural characteristics of the pebbles can be determined without thin-sectioning.

The source of the oolitic pebbles is not known. The textures and character of many of the pebbles are approximated or essentially duplicated in the oolite of the Ste. Genevieve and Salem formations, as now exposed in Illinois, which may have been the source of many of these pebbles.

It is of interest that no considerable amount of oolitic chert is known in the Salem, Ste. Genevieve, or Chester formations as now exposed in southern or western Illinois. As previously noted, some of the oolite pebbles composed of relatively coarse-grained quartz show natural surfaces like those of a freshly broken piece of limestone oolite, a type of fracture which would probably not be expected from the silicified pebbles as now found (fig. 8). This phenomenon can be accounted for in various ways, but the question is raised whether these pebbles may not be the result of some special set of silicification conditions rather than those which normally produce chert in limestones.

FIG. 9.—Polished section of a "Lafayette" pebble showing white "glaze" over part of exterior, and a light band concentric with the glaze. Reflected light. X 8.

"GLAZED" PEBBLES

The samples studied, especially nos. 1 and 2, contain pebbles whose exterior consists partly or wholly of white, siliceous, often porcelain-like material resembling a "glaze"[7] or coating (fig. 9). On some pebbles the glaze is about 1/8 of an inch thick and covers most of the surface. Other pebbles show only small glazed areas. The glaze occurs alike on brown and black chert pebbles. Both the unglazed and glazed parts of many of the pebbles are polished in normal

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[7] The term "glaze" is here used in the same sense as a ceramist would refer to an opaque glaze because the term describes the appearance of the phenomenon. This usage is not meant to connote that the glaze was necessarily an addition to the original pebble.

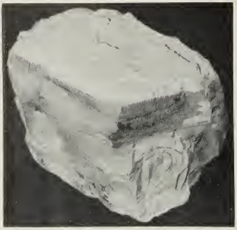

Fig. 10.—Chert from a bedrock outcrop showing the development of a white chalky material on the top of the specimen. Similar material occurs on the bottom but is not visible in the photograph. The white chert in other parts of the specimen is not chalky. About natural size.

fashion. No glaze was observed on sandstone, vein quartz, or quartzite pebbles. In sample 1, 22 of the 50 pebbles examined had more or less glaze; 4 of the 50 pebbles in sample 2 had glaze.

The origin of the glaze cannot be certainly determined from the material at hand. It is suggested, however, that a porous, white, weathered zone, such as commonly develops on chert (fig. 10), was later impregnated with silica to produce the hard, dense exterior material, or glaze. Different degrees of erosion of the weathered zone, possibly before impregnation, would account for the differences in the amount of glaze now evident.

Agate Pebbles

Samples 1, 2 and 3, from the Mississippi Valley, contain pebbles of agate, mostly in shades of gray, white, and brown. These pebbles are not numerous, but they are significant because they are rare or absent in the other samples. They were observed to be also relatively common in the ''Lafayette'' gravel in Missouri across the Mississippi River from the deposit in Alexander County, Ill., from which sample 2 was obtained. The agate pebbles are rounded to irregular.

In sample 1, two brown chert pebbles were partly coated with banded quartz similar to parts of the agate pebbles.

The agate pebbles are of different types. A common variety is of crystalline quartz, showing comb structure in some specimens, which is interspersed between irregular masses of banded chalcedony and within which round agates as much as ½ inch in diameter are distributed. In one pebble studied in detail, the contact between the comb quartz and the banded chalcedony is transitional and consists of a series of thin alternating bands of crystalline quartz and chalcedony. The crystal size of the macro-crystalline quartz bands decreases away from the comb quartz and ultimately becomes micro-crystalline.

The general structure and character of the pebbles suggest that they were originally cavity linings or fillings. The chert coated with banded silica presumably represents part of a cavity lining and cavity wall.

No deposits from which the agate pebbles could have come are known in Illinois. Their presence along the Mississippi Valley suggests that they may have come from Missouri or other areas adjacent to the valley.

TABLE 6.—FAUNA LIST*

Sample No.	Location	Name	Age
2	Grover, Mo.	Favosites	Silurian to Devonian
		Lithostrotion	Mississippian
3	Fayville, Ill.	Favosites	Silurian to Devonian
		Columnaria alveolata?	Upper Ordovician
		Streptelasma	Ordovician
		Lithostrotion	Mississippian
		Triplophyllum	"
		Cyathophyllum	Devonian and Mississippian
4	Mounds, Ill.	Lithostrotion	Mississippian
		Triplophyllum	"
		Linoproductus	Mississippian to Permian
		Spirifer	Silurian to Pennsylvanian
5	Grand Chain, Ill.	Lithostrotion	Mississippian
6	Renshaw, Ill.	Lithostrotion	Mississippian
		Fenestellid bryozoa	Silurian to Permian
		Zaphrentid corals	" " "

* Identification and age by W. H. Easton, Illinois State Geological Survey, 1942.

FOSSILS

Silicified fossils, commonly as partial specimens of individuals, are relatively abundant in some deposits of "Lafayette" gravel. Corals are most frequent. Some chert fragments contain a great many crinoid stems, and molds or partial molds of brachiopods, bryozoa, and gastropods. Table 6 lists the genera which were obtained as a result of limited collecting.

Undoubtedly a systematic collection from each locality would yield more detailed lists of fauna. The presence of fossil corals, crinoids, and brachiopods of the Lower and Middle Silurian is reported[8] in a deposit of Lafayette-type gravel in Henry County in northwestern Illinois. The data in table 5 suggest that there is no need to assume a distant source for the fossiliferous chert in any of the southern Illinois "Lafayette" deposits studied, as southern Illinois or areas adjacent to it contain outcrops of limestone, some of it cherty, of Ordovician, Silurian, and Mississippian age and also extensive deposits of Devonian chert formations, especially near the localities from which samples 3 and 4 were taken. The Grover deposit is similarly situated with reference to outcrops of Ordovician, Silurian, and Mississippian rocks.

CONCLUSIONS

It appears from the foregoing that a study, including particle size distribution, particle shape, pebble counts, and paleontology of fossil molds, of a greater number of samples taken with cognizance of the relation of the deposits to topo-

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[8] Horberg, Leland, Preglacial gravels in Henry Co., Illinois. Trans. Ill. Acad. Sci. vol. 43, 1950, p. 173.

graphic levels might yield information which would add materially to the knowledge of the source or sources of the "Lafayette" gravel in Illinois and adjacent states, and which would also broaden the factual basis for interpreting the history of the formation of the gravel. Various special features, such as polish, glazed pebbles, agate pebbles, and silicified oolite pebbles, are in themselves problems that merit further investigation and that may aid in a better understanding of the broader problems of the "Lafayette" gravel.

CAMBRIAN AND LOWER ORDOVICIAN EXPOSURES IN NORTHERN ILLINOIS*

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Drilling in central northern Illinois has revealed the presence of Cambrian and lower Ordovician strata beneath glacial drift in a large area south of the Sandwich fault zone, as shown on the state geologic map (Weller and others, 1945), and one exposure of Cambrian strata at Oregon, Ogle County, Ill., has long been known (Bevan, 1929, 1935, 1939). No other Cambrian exposures and no exposures of lowermost Ordovician have been recognized previously in Illinois.

The present study has shown that exposures west of the area mapped as Cambrian, formerly believed to be of Shakopee, Platteville, or Galena age, actually belong to the Cambrian Trempealeau formation and to the lower Ordovician Gunter and Oneota formations. The area underlain by Cambrian and lower Ordovician rocks has been extended westward from Rochelle nearly to Rock River, and the Sandwich fault zone has been traced west of Rock River (fig. 1). Outcrops near Millbrook, Kendall County, previously assigned to the Galena formation, now are known to be Oneota. The exposures show that at least the lower part of the Trempealeau formation in this region is a reef-type dolomite.

Identification of the formations has been based mainly upon lithology as revealed by samples from wells, but partly upon fauna. The exposure at Oregon lies near the crest of the Oregon anticline, but all of the remaining exposures are near the crest of a major uplift on the south side of the Sandwich fault zone, herein named the Ashton Arch (figs. 1, 4). The exposures all are located on preglacial bedrock uplands (Horberg, 1950, plate 1, sheet 1). The absence of outcrops between the Fox River and Rochelle is explained by the presence of two major southward-trending preglacial valleys and deposition of a thick Wisconsin morainic belt over the site of the valleys.

STRATIGRAPHY

The exposed pre-St. Peter formations of central northern Illinois are shown in columnar section in figure 2, and are described below.

Franconia formation. — The Franconia formation, the oldest formation exposed in Illinois, is known to crop out only in the lower part of an abandoned quarry 3,700 feet from the north line and 1,100 feet from the east line of sec. 3 (elongate), T. 23 N., R. 10 E., Ogle County (Oregon quadrangle), one-half mile east of Oregon (fig. 1). The exposure is poor and has a total thickness of about 30 feet. It consists mainly of argillaceous, silty, glauconitic and muscovite-bearing, partly dolomitic, greenish-gray sandstone which ranges from very fine grained to coarse grained, but is

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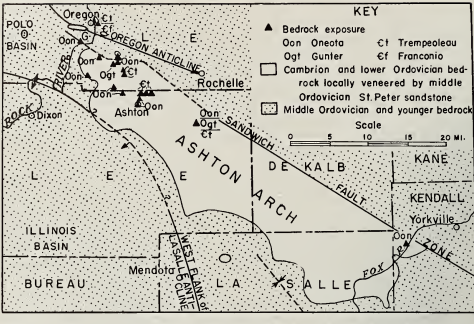

FIG. 1.—Location of Cambrian, Gunter, and Oneota exposures in northern Illinois.

mostly fine grained. The grains are clear and mainly angular, although the medium and coarse grades are rounded. Abundant scattered fine pellets of dark green glauconite give the rock a "salt-and-pepper" aspect. Green glauconitic clay occurs as partings between the beds and as streaks and mottlings within the beds. The heavy mineral suite consists of abundant garnet, with subordinate amounts of tourmaline and zircon. The sandstone is laminated and friable. It is in lenticular to regular beds from a fraction of an inch to 9 inches in thickness. A one-foot bed of impure, buff, chalky dolomite in thin irregular layers is present 20 feet below the top of the formation (fig. 3), and scattered dolomite lenses occur elsewhere. Partings of silty, partly dolomitic, olive-gray, laminated, friable shale are common.

The following fossils from the sandstone, identified by G. O. Raasch, show that the strata belong to the Bad Axe or highest member of the Franconia formation: *Dikellocephalus n. sp., Illaenurus n. sp., Saukiella minor* Ulrich and Resser, and *Trilobita n. gen. and sp.* In addition, small fragments of oboloid brachiopod shells are common, and ropy excremental worm-castings cover many bedding surfaces.

Subsurface data indicate that the Franconia formation, exclusive of Ironton strata, ranges from 65 to 120 feet thick in north-central Illinois. The middle portion of the formation consists of sandy, glauconitic dolomite and limestone, but the lower part is composed of sandstone and sandy dolomite like the higher, exposed beds. A thin, dolomitic, coarsely glauconitic, coarse-grained sandstone, formerly regarded as the

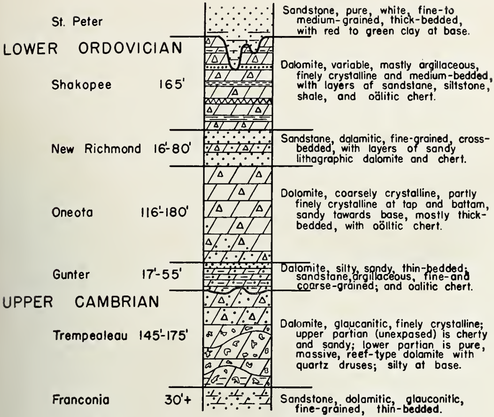

Fig. 2.—Pre-St. Peter formations exposed in northern Illinois.

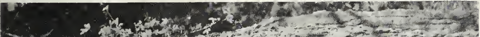

Fig. 3.—Franconia strata in quarry at Oregon, Illinois; hammerhead is at base of dolomite bed lying 20 feet below top of formation.

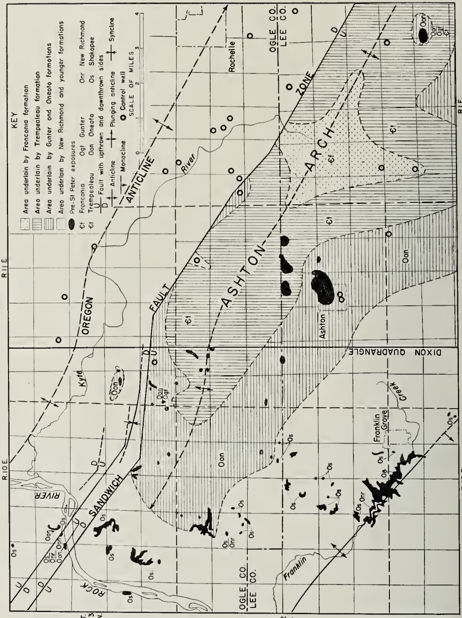

FIG. 4.—Geologic map of parts of Lee and Ogle counties.

FIG. 5.—Trempealeau dolomite in quarry at Prairie Star School, SW¼ SW¼ SE¼ Sec. 5. T.22 N., R.11 E., Ogle County, Ill.

basal member of the Franconia, now is considered the top unit of the Ironton formation. The Franconia formation is correlated tentatively with the Davis, Derby, and Doerun formations of Missouri (Workman and Bell, 1948, p. 2053).

Trempealeau formation. — Twenty-three feet of basal Trempealeau dolomite overlies Franconia sandstone in the quarry at Oregon. An extension of this exposure is found in a low ridge littered with Trempealeau float ¾ mile northwest of the quarry, 500 feet from the north line of sec. 3 and 1,700 feet from the west line. The major Trempealeau exposures found in this study are as follows (fig. 4):

(1) Quarry at Prairie Star School, 7 miles southeast of Oregon, SW¼ SW¼ SE¼ sec. 5, T. 22N., R. 11 E., Ogle County (Dixon quadrangle), where 18 feet is exposed (fig. 5).

FIG. 6.—Trempealeau and Gunter dolomites in quarry south of Rochelle, N. line NE¼ SE¼ NE¼ Sec. 26, T. 39 N., R. 1 E., Lee County, Ill.

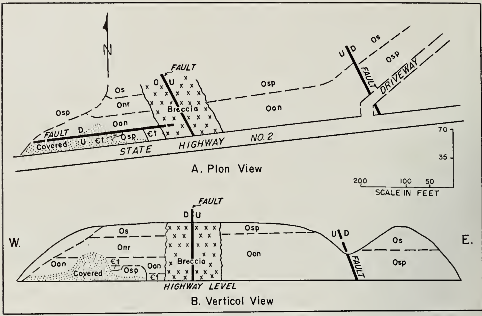

Fig. 7.—Diagrammatic sketch of pre-St. Peter exposures in hill on north side of State Highway No. 2, NE¼ SE¼ SE¼ Sec. 17, T.23 N., R.10 E., Ogle County, Ill. Ct, Trempealeau; Oon, Oneota; Onr, New Richmond; Os, Shakopee; Osp, St. Peter, mainly filling pre-St. Peter channels.

(2) Three quarries 1½ miles northeast of Ashton, NW¼ NW¼ NE¼ sec. 22, SE¼ NW¼ NW¼ sec. 23, and NE corner sec. 23, T. 22 N., R. 11 E., Lee County (Rochelle quadrangle), where 14 to 22 feet of dolomite is exposed.

(3) Quarry 6 miles south of Rochelle, N. line NE¼ SE¼ NE¼ sec. 26, T. 39 N., R. 1 E., Lee County (Rochelle quadrangle), where 6 feet of dolomite is exposed, with 5 additional feet below water level (fig. 6).

(4) Bank on north side of State Highway 2, 2½ miles southwest of Oregon, NE¼ SE¼ SE¼ sec. 17, T. 23 N., R. 10 E., Ogle County (Dixon quadrangle), where 4 feet of dolomite is exposed at road level and 3 feet is exposed 15 feet above road level (fig. 7).

A few small outcrops of Trempealeau dolomite occur in the vicinity of the principal exposures (fig. 4). The area has not been mapped in detail, and other outcrops may be present.

The Trempealeau formation is composed of light buff, finely crystalline to medium crystalline, reef-type dolomite, which is finely porous to vuggy, and occurs mainly in irregular beds from 1 to 4 feet thick. The basal beds at Oregon are glauconitic and silty, but the dolomite in the remaining and stratigraphically higher exposures is pure. Many vugs are lined with white to pink crystalline quartz which readily differentiates the Trempealeau from other formations in this region. In places the bedding disappears into or is draped over structureless columnar masses of dolomite more than 10 feet thick, which are interpreted as reef-cores of algal origin. Weathered bedding surfaces commonly are covered with a network of low, narrow, vertically-sided ridges, and weathered faces are marked by narrow, irregular, vertical flutings; these phenomena also may be of algal origin. The rock contains algal domes and rare trilobite and gastropod remains. G. O. Raasch has identified the following forms: *Cryptozoon sp. Hypseloconus sp. nov.,* and *Saukiella sp., cf. indenta* Ulrich and Resser.

In the subsurface of central northern Illinois the Trempealeau formation ranges from 145 to 175 feet thick where not reduced by pre-St. Peter erosion. It consists of (1) a lower, partly glauconitic dolomite containing quartz-lined vugs, without disseminated sand except in places at the base, and (2) an upper, cherty, mostly sandy dolomite which lacks quartz-lined vugs and commonly is non-glauconitic. All of the exposed Trempealeau belongs to the lower unit, which is correlated with the Potosi formation of Missouri (Workman and Bell, 1948, p. 2053) and with the St. Lawrence and Lodi members of the Trempealeau formation in Wisconsin.

South of the area of Trempealeau exposures glauconite in the lower unit occurs in three discontinuous zones of irregular thickness (Willman and Payne, 1942, pp. 56-57). The upper unit apparently is not exposed. Although it is encountered in wells at Ashton and Dixon, Lee County, it lenses out northward and is absent at Rochelle and elsewhere in Ogle County. The upper unit is correlated with the Eminence formation of Missouri (Workman and Bell, 1948, p. 2053) and with the Jordan and Madison members of the Trempealeau formation in Wisconsin. Continuous subsurface tracing of the Illinois Trempealeau units into the Wisconsin outcrop area is prevented by the presence of a major westward-trending pre-St. Peter valley just north of the Cambrian exposures, along which much or all of the Trempealeau formation has been removed (Meyer, 1948).

In Wisconsin the Franconia-Trempealeau contact is marked by a diastem (Twenhofel, Raasch and Thwaites, 1935, pp. 1705-1706, 1717), but in the Illinois subsurface, Franconia-Trempealeau relations are conformable and nearly gradational. The contact at Oregon is concealed by a short covered interval. The Trempealeau-Oneota[1] contact in Wisconsin seems unconformable (Twenhofel, Raasch and Thwaites, 1935, pp. 1712, 1718). In the Illinois subsurface the Trempealeau-Gunter contact is abrupt, and in the quarry at Rochelle it is sharp and undulatory, with a relief of six inches. These features, together with the absence of upper Trempealeau (Eminence) strata in Ogle County, suggest that a diastem or unconformity also separates the Trempealeau and Gunter formations in northern Illinois.

Except at Rochelle the exposed Trempealeau is overlain unconformably by St. Peter sandstone or by glacial drift. At Oregon the upper Trempealeau beds in places have

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[1] Although the Gunter formation is present in Wisconsin, it has not been differentiated from the Oneota formation.

been leached and altered to siltstone to a depth of at least 4 feet by pre-St. Peter weathering, and just south of the quarry the Cambrian strata abut against a channel-filling of St. Peter sandstone. Post-St. Peter thrust-faulting has altered the sandstone overlying the Trempealeau formation to a quartzite-breccia (Bevan, 1935, p. 384).

Gunter formation.—In wells in central northern Illinois, 17 to 55 feet of impure dolomite and sandstone lies between the Trempealeau and Oneota dolomites. In the past these beds have been variously assigned to the Jordan, Gunter-Jordan, or Oneota formations. Recent studies have shown that they are very similar lithologically to the type Gunter formation of Missouri, and can be traced into that formation; they also can be traced to southern Wisconsin, where they overlie the latest Cambrian Madison sandstone and are included in the Oneota formation. Differentiation of Gunter strata thus involves a slight redefinition of the term Oneota as used in Iowa and Wisconsin. In Minnesota the Kasota and Blue Earth formations (Powell, 1935) probably are equivalent to all or part of the Gunter formation.

Known Gunter exposures in Illinois are confined to the quarry 6 miles south of Rochelle, described above under Trempealeau formation, and to a small exposure in a prospect pit and ravine, NW¼ NW¼ SW¼ sec. 31, T. 23 N., R. 11 E., Ogle County (Dixon quadrangle), 5 miles southeast of Oregon (fig. 4). In the Rochelle quarry (figs. 6, 8) the Gunter formation is 10 feet 3 inches thick, and consists principally of argillaceous, silty, finely glauconitic, greenish-gray to cream, chalky dolomite which contains very fine muscovite flakes, and is slightly sandy in the lower 2 feet 9 inches. The dolomite is in irregular, laminated beds from 1 to 12 inches thick, separated by green clay partings. Some layers are algal and have highly undulatory bedding surfaces. Irregular masses of oolitic chert are common near the base and middle of the formation. Five feet below the top of the Gunter is a 30-inch bed of buff, medium crystalline, vuggy, cherty dolomite which closely resembles the overlying Oneota formation. The exposure 5 miles southeast of Oregon is very poor, and is composed of eight feet of impure, thin-bedded dolomite like that at Rochelle, but partly maroon. The

FIG. 8.—Gunter and Oneota dolomites in quarry south of Rochelle, N. line NE¼ SE¼ NE¼ Sec. 26, T. 39 N., R. 1 E., Lee County, Ill.

Gunter here is overlain by two feet of Oneota dolomite, but no Trempealeau strata are exposed.

In subsurface (Workman and Bell, 1948, pp. 2054-2055) the Gunter formation consists of (1) very fine- to coarse-grained, poorly sorted to locally well sorted, incoherent sandstone, (2) varicolored dolomite which is chiefly chalky to lithographic and dense, and is partly argillaceous, silty or sandy, (3) varicolored, oolitic to locally sandy chert which is principally white to orange, and (4) small amounts of slightly sandy, blue-green and dark-red, laminated, hard, smooth shale.

The sandstone ordinarily is clean and white, but locally is argillaceous and gray-green. The fine sand is angular; the medium and coarse sand is mostly rounded, although some grains have been made angular by secondary crystalline quartz. The poorly sorted sandstone normally contains free, medium to coarse, siliceous oolites. A five-foot bed of argillaceous, fine- and coarse-grained sandstone marks the top of the Gunter in wells between Dixon and Oregon, but lenses out eastward before reaching Ashton.

Small *Cryptozoön* domes in the quarry south of Rochelle are the only fossils observed in Gunter strata.

Oneota formation.—The principal exposures of the Oneota formation in northern Illinois are as follows (figs. 1, 4):

(1) On the west side of Fox River opposite Millbrook, Kendall County, where 12 feet crops out in a stream channel at a breached earth dam, SE¼ NW¼ SE¼ sec. 8, T. 36 N., R. 6 E. (Sandwich quadrangle); 10 feet is exposed in a small quarry, SE corner NE¼ NE¼ SE¼ sec. 8, and 2 feet is exposed in an abandoned quarry, SW corner SW¼ SW¼ NW¼ sec. 9.

(2) In the quarry 6 miles south of Rochelle, where 31 feet is exposed (fig. 8), and in a shallow quarry ¼ mile eastward.

(3) At Ashton, Lee County, in three quarries in the NW¼ sec. 27, in two quarries on opposite sides of the road along the north line of the E½ sec. 27, just east of State Highway 330, and in a shallow quarry in the center of the NE¼ sec. 27, T. 22 N., R. 11 E. (Rochelle quadrangle). Here from 10 to 31 feet of rock is exposed in the individual quarries, and the total stratigraphic interval represented in the quarries exceeds 50 feet.

(4) Shallow quarries 2 and 3½ miles northwest of Ashton, W. line NE¼ NE¼ NW¼ sec. 20 and NW¼ NW¼ SW¼ sec. 18, T. 22 N., R. 11 E., Lee and Ogle counties, exposing 8 and 16 feet of dolomite, respectively.

(5) Quarry 5 miles southeast of Oregon, S. line SE¼ NW¼ NE¼ sec. 31, T. 23 N., R. 11 E., Ogle County, exposing 12 feet of deeply weathered rock.

(6) Quarry and ravine 4 miles south of Oregon, SW¼ SW¼ sec. 26, T. 23 N., R. 10 E., Ogle County, exposing 45 feet of dolomite.

(7) Cut on north side of State Highway 2, two miles south of Oregon, NE¼ SE¼ SE¼ sec. 17, T. 23 N., R. 10 E., Ogle County.

(8) Ravine 6 miles south of Oregon, SE¼ SE¼ SE¼ sec. 4, T. 22 N., R. 10 E., Ogle County, where 35 feet of dolomite crops out.

Localities 4 through 8 are located in the Dixon quadrangle. A few other small, scattered exposures less than 5 feet thick also occur near the principal localities listed above (fig. 4).

Most of the Oneota formation consists of light-gray to blue-gray, uniformly coarsely crystalline, dense, cherty dolomite in massive beds as much as 15 feet thick. Most individual crystals range from 1 to 2 mm. in diameter, and make the rock the most coarsely crystalline dolomite in the Illinois Paleozoic sequence. Upon weathering the dolomite breaks down into regular, friable, 6- to 24-inch beds with dull brown-gray, coarsely "sandy" surfaces, and the interior turns light buff with white flecks representing decayed cement between the dolomite crystals. Vertical faces generally are regular, although occasional beds have a brecciated or pseudofucoidal structure and a rough face. Bedding surfaces are rough but have low relief. Except for occasional green clay films within the beds the rock is pure. At one locality (No. 8) thirty-five feet of upper Oneota dolomite is mainly finely crystalline and weathers to a coarsely pitted face; these features have not been noted elsewhere and apparently reflect local facies-change.

Basal Oneota strata exhibit considerable differences from the main body of the formation. Much of the lowermost 9 to 10 feet is lithographic to finely crystalline, is in regular 2- to 8-inch layers with smooth bedding surfaces, and weathers deep buff. In the quarry south of Rochelle some boulder-like, algal masses of lithographic limestone are present in this basal zone; greenish-gray to buff shale partings are common, and the upper 6 inches of the zone are silty and laminated. Here the basal zone represents a transition from Gunter to typical Oneota sedimentation.

Gray, white, and light yellow to pink or red chert, most of which is sandy, oolitic, conglomeratic, or strongly banded, occurs throughout the Oneota formation. In places the chert forms layers, lenses, or spheroidal masses as much as 1 foot thick, but in others it consists of numerous small, irregularly shaped and oriented, angular fragments which locally form a disconnected meshwork within the beds. The lower 12 to 60 feet of the formation ordinarily are finely glauconitic and somewhat sandy; a few sandy streaks are found at higher horizons.

Cryptozoön is present to common in nearly all Oneota exposures and forms conspicuous small domes on the floor of the quarry at Ashton, center NE¼ sec. 27 (part of Locality 3). Gastropod molds preserved mainly in chert from the quarry at Ashton, SW¼ SW¼ SE¼ sec. 22 (part of Locality 3) have been identified as: *Gasconadia putilla* (Sardeson), *Ophileta sp.*, *Rhachopea sp.*, and *Sinuopea sp.* Identifiable fossils other than *Cryptozoön* have not been seen elsewhere. The fauna is typical of the Oneota formation of Wisconsin and the Gasconade formation of Missouri (Ulrich, Foerste and Bridge, 1930, pp. 186-222; Branson, 1944, pp. 35-47). Correlation of this exposure with cuttings from two Chicago and North Western Railway wells at Ashton (Illinois Geological Survey, sample sets 289 and 402), ½ mile south, show that the quarry floor is not less than 60 feet above the Gunter-Oneota contact. Part or all of this concealed interval is believed equivalent to the Van Buren formation of Missouri (Workman and Bell, 1948, p. 2056).

The total thickness of the Oneota dolomite in central northern Illinois ranges from 116 to 180 feet. The formation shows pronounced thinning along the crest of the western part of the Ashton arch.

The contacts of the Oneota dolomite with the adjacent Gunter and New Richmond formations seem conformable. Although Payne (Willman and Payne, 1942, pp. 58-59) reports an unconformity between the Gunter ("Jordan") and Oneota formations to the southward, the presence of such an unconformity has not been confirmed by recent studies.

New Richmond formation.—The New Richmond formation superficially resembles the St. Peter sandstone. However, it generally (1) has finer, more angular, less frosted grains, which more frequently are enlarged by secondary crystalline quartz, (2) is less well sorted, (3) contains free siliceous oolites and grains or nodules of chert, (4) has a much higher proportion of heavy minerals, with abundant accessory tourmaline, considerable ilmenite and leucoxene, and some garnet, (5) is much thinner-bedded and more strongly cross-bedded, and (6) is better cemented. It contains beds of lithographic dolomite and dolomite-cemented sandstone, has green argillaceous streaks in the upper part, and has gray, blue, or red shale layers in the lower portion (Willman and Payne, 1943, pp. 532-533; Workman and Bell, 1948, pp. 2057-2058). In central northern Illinois its thickness ranges from 16 to 80 feet, and increases rapidly to a known maximum of 190 feet at Starved Rock State Park, LaSalle County. It is correlated with the Roubidoux formation of Missouri, which carries the distinctive *Lecanospira* fauna.

Exposures of New Richmond in Illinois previously had been known only along Franklin Creek, Lee County, and Fox River, LaSalle County (Cady, 1920, p. 107; Knappen, 1926, pp. 40-43; Willman and Payne, 1943, pp. 532-533). The present study revealed poor exposures in (1) a small quarry 3½ miles east of Grand Detour, SE¼ SE¼ NW¼ sec. 9, T. 22 N., R. 10 E., Ogle County (Dixon quadrangle), where 3 feet of sandstone is exposed beneath Shakopee dolomite, and (2) a cut on the north side of State Highway 2, two miles south of Oregon, NE¼ SE¼ SE¼ sec. 17, T. 23 N., R. 10 E., Ogle County (Dixon quadrangle), where 11 feet of sandstone, with covered intervals above and below, crops out between Oneota and Shakopee strata. Samples from both outcrops are slightly dolomitic and show the typical New Richmond heavy mineral suites (table 1). It is very probable that other outcrops of New Richmond exist in the northeast quarter of the Dixon quadrangle, where they have not been differentiated from St. Peter sandstone. Because the New Richmond offers little resistance to erosion, exposures not on major stream channels are mostly veneered by soil or Shakopee float.

Table 1.—Heavy Mineral Analyses of New Richmond Sandstone in Northern Illinois, in Percent

Locality	1	2	3	4
Garnet	3.0	17.0	3.0	0.6
Ilmenite	17.0	17.0	20.0	4.4
Leucoxene	22.0	10.0	18.0	13.5
Magnetite	1.0	6.0	2.0	....
Tourmaline	42.0	35.0	36.0	55.5
Zircon	12.0	10.0	15.0	26.2
Miscellaneous	3.0	5.0	6.0	....
Percent of heavy minerals by weight	0.006	0.003	0.006	....

Locality 1: 5′ below top of sandstone in bluff on north side of Franklin Creek, N. line SE¼ NW¼ SW¼ sec. 34, T. 22 N., R. 10 E., Lee County. *Locality 2:* 2′ below top of sandstone in quarry, SE¼ SE¼ NW¼ sec. 9, T. 22 N., R. 10 E., Ogle County. *Locality 3:* 15′ below top of sandstone in bluff on west side of State Highway 2, NE¼ SE¼ SE¼ sec. 17, T. 23 N., R. 10 E., Ogle County. *Locality 4:* Average of 19 samples from upper 23 feet of sandstone at ravine mouth, NW¼ SW¼ SW¼ sec. 8, T. 35 N., R. 5 E., LaSalle County. Analyses for localities 1, 2 and 3 by T. C. Buschbach; analyses for locality 4 by Paul Herbert, Jr.

Shakopee formation.—The Shakopee formation consists of irregular, alternating, varicolored beds of dolomite, shale, siltstone, and sandstone, with dolomite greatly predominating. The dolomite shows great variation in purity, color, crystal size, porosity, and bedding. Most of it is argillaceous, silty, sandy, cherty, locally glauconitic, light gray to yellow-buff, chalky to finely crystalline, dense, and thin-bedded. Brecciated and conglomeratic beds are very common. Bedding surfaces generally are ripple-marked and mud-cracked, and show occasional molds of cubic salt crystals. Beds of relatively pure, medium crystalline dolomite, as much as 18 inches thick, are common in the lower part of the formation. Although such beds locally resemble Oneota dolomite they lack the distinctive chert layers, chert fragments, and coarsely "sandy" weathered surfaces of the latter formation, are thinner-bedded, and contain thin interbeds of typical Shakopee argillaceous dolomite. The chert is mostly oolitic, but partly sandy or conglomeratic. The sandstone heavy mineral suites have a higher percentage of garnet and ferromagnesian minerals than do those of the New Richmond sandstone (Willman and Payne, 1943, p. 535). Several layers of bentonite are present in a quarry in the SW¼ SE¼ NW¼ sec. 6, T. 23 N., R. 10 E., Ogle County (Oregon quadrangle), 2½ miles west of Oregon.

The thickness of the Shakopee in central northern Illinois ranges from zero to about 165 feet, but increases rapidly to more than 600 feet in south-central Illinois. The Shakopee is correlated with the Jefferson City and Cotter formations of Missouri (Workman and Bell, 1948, pp. 2058-2060), although equivalents of younger Missouri formations may be included locally.

The Shakopee dolomite rests conformably on New Richmond sandstone, but is separated from the overlying St. Peter sandstone by a major unconformity.

Known exposures of the Shakopee formation in Illinois are found (1) along the Illinois River and its tributaries from LaSalle east to Utica, LaSalle County (Cady, 1919, pp. 35-36), (2) along Fox River near Sheridan and Millington, in LaSalle and Kendall counties (Willman and Payne, 1943, pp. 534-538), and (3) along Rock River and its tributaries between Franklin Grove, Lee County, and a point 2½ miles west of Oregon, Ogle County. Its distribution in the latter area is shown in fig. 4.

STRUCTURAL GEOLOGY

Ashton arch.—Most of the Cambrian and lower Ordovician exposures described above lie on the crest or flanks of a major anticline which trends N. 60° W. across northern Illinois from central western Will County to central Ogle County, and which is here named the Ashton arch (figs. 1, 4). The name is derived from the town of Ashton, Lee County, which is located near the crest of the western portion of the arch, and near which Cambrian and lower Ordovician formations, brought to the surface by the arch, are well exposed.

The Ashton arch first was recognized by Cady under the name Ogle, Lee, and LaSalle counties anticline (Cady, 1920, pp. 90, 127-128, fig. 8), although later studies modified the original concept of its location and extent. It formerly was considered to mark the crest of the Kankakee arch, a broad uplift which connects the Cincinnati and Wisconsin arches and separates the Illinois and Michigan basins (Pirtle, 1932, p. 149, fig. 1; Ekblaw, 1938). However, it has been found (1) that the pre-St. Peter axis of the Kankakee arch passes through the northeast corner of Illinois (Bays and others, 1945; Cohee, 1945, fig. 4; Meyer, 1948) and (2) that the post-St. Peter axis (Cohee, 1945, fig. 5; 1948, p. 1441, fig. 1) merges into the east flank of the Hersher anticline which is separated from the Ashton arch by a northward-trending syncline (fig. 9). Accordingly it appears desirable to introduce a separate name, Ashton arch, for the relatively local uplift between Will and Ogle counties.

The Ashton arch is bounded on the north throughout most or all of its length by the Sandwich fault zone. A graben and a syncline separates the western part of the arch from the smaller, parallel Oregon anticline on the north (fig. 4). A syncline also separates the eastern portion of the arch from the LaSalle anticline (fig. 9). The LaSalle anticline merges into the arch along the LaSalle-Lee County boundary, and cannot be distinguished farther north. However, a southward prong of the arch, which may represent a continuation of the LaSalle anticlinal trend, extends northwestward from Dixon to the Savanna-Sabula anticline. The southwestward flank of the Ashton arch dips steeply into the Illinois basin. The western end plunges into the small but deep Polo basin, named herein from the town of Polo, Ogle County, which lies on the west side of the basin.

The Ashton arch has a length of 80 miles and a width of 17 to 25 miles. The structural relief on the southwestern side is about 1,900 feet, and the maximum relief on the northern side at least 900 feet. The axis of the arch is at, or a short distance south of, the Sandwich fault

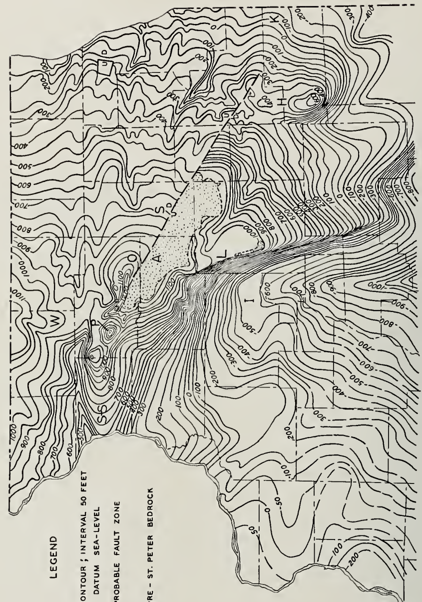

FIG. 9.—Structure contours on top of Galena dolomite in northern Illinois, modified from Horberg, 1946. A, Ashton arch; H, Hersher anticline; I, Illinois basin; K, Kankakee arch; L, LaSalle anticline; O, Oregon anticline; P, Polo basin; S, Sandwich fault zone; S-S, Savanna-Sabula anticline; W, Wisconsin arch.

zone. The arch has a broad, nearly flat summit area, most of which dips very gently southward. The steepest dips on the structure, found on the southwest flank, are only from 1° to 3°.

Sandwich fault zone and Oregon anticline.—The Sandwich fault zone parallels the strike of the Ashton arch and bounds the northeastern side of the arch for most or all of its length. It has been traced from southern Will County to a point in northeastern Lee County 6 miles south of Rochelle, a distance of 68 miles, and probably continues at least 20 miles farther, to a point 2½ miles southwest of Oregon, in central Ogle County (figs. 1, 4, 9). The fault zone has a maximum downthrow of at least 900 feet on the northeast side. Because the fracture appears to be compound rather than single the term fault zone is applied.

Between Rochelle and Oregon the structure on the northeastern or downthrown side of the fault is complicated by a sharp uplift called the Oregon anticline (Bevan, 1935), the crest of which approximately parallels the Ashton arch and Sandwich fault zone and lies from 2 to 3 miles northward from the latter. The Cambrian exposure at Oregon, a small Oneota exposure in the SE¼ SE¼ NE¼ sec. 30, T. 22 N., R. 11 E., Ogle County (Dixon quadrangle), and a Shakopee exposure in the SW¼ SE¼ NW¼ sec. 6, T. 23 N., R. 10 E., Ogle County (Oregon quadrangle), are located on the anticline. The Oregon anticline continues northwestward to join the Savanna-Sabula anticline. A synclinal belt separates the Oregon-Savanna-Sabula anticlines and associated branch uplifts from the main body of the Wisconsin arch on the north.

A narrow graben and a tightly compressed syncline, bounded on the south by the Sandwich fault zone, separate the Oregon anticline from the Ashton arch (fig. 4). The graben is well exposed in the cut on the Chicago, Burlington, and Quincy Railroad, just south of the center of sec. 7, T. 23 N., R. 10 E., where a dropped block of Galena dolomite is bounded by faults which bring the top of the St. Peter sandstone on the southwest and lower Platteville beds on the northeast to the same elevation as the Galena strata. The throw on the south side of the block is more than 165 feet and that on the north side is over 130 feet. The block is about one-half mile wide and is cut by numerous minor step-faults. Sharp synclinal folding within the graben is well developed in Platteville strata exposed at intervals from the NW¼ SW¼ SE¼ sec. 26, T. 23 N., R. 10 E., to the NE¼ NW¼ NE¼ sec. 31, T. 23 N., R. 11 E., Ogle County (Dixon quadrangle), where northward dips range from 2° to 10° and southward dips from 14° to 30°.

Structural history. — The major movement along the LaSalle anticline in northern Illinois was post-Mississippian, pre-Pennsylvanian, followed by lesser uplift in post-Pennsylvanian time (Payne, 1939). On the Ashton arch, Sandwich fault zone and Savanna-Sabula anticline, and probably on the Oregon anticline as well, the principal movement was at least post-Silurian, and may have taken place at about the same time as uplift on the LaSalle anticline. It is uncertain whether the

Ashton arch owes its present form solely to downthrow along the northern side of the Sandwich fault zone, or whether the arch formed prior to the faulting.

The general northwestward to westward structural grain of northern Illinois (fig. 9) is affected by subordinate northeastward-trending cross folds of uncertain age. It is possible that the post-St. Peter Kankakee arch of northwestern Indiana, uplifted mainly in post-Pennsylvanian time, once was continuous with the Ashton arch, but was separated from it by later cross folding.

There is considerable evidence for pre-St. Peter deformation in the area occupied by the Ashton arch, although generally it cannot be proved that the trend of the deformation paralleled that of the present structure. Upper Trempealeau (Eminence) strata thin or wedge out northward over the arch, but reappear in northernmost Illinois and southern Wisconsin, across a major pre-St. Peter valley. The Oneota formation thins conspicuously over at least the western part of the arch, parallel to its general trend. The earlier movements culminated in uplift, folding, and erosion in post-Shakopee, pre-St. Peter time. At places in Lee and Ogle counties Shakopee strata are thrown into close folds which do not affect the overlying St. Peter sandstone (Knappen, 1926, pp. 83-84, 111); although formerly attributed to pre-St. Peter slumping, the folding is considered diastrophic by the writers. Along Fox River in LaSalle and Kendall counties the Shakopee shows steep dips which do not accord with the gentler post-St. Peter structure in amount or direction (Willman and Payne, 1943, fig. 1). At Oregon, Ogle County, a post-Shakopee, pre-St. Peter fault cutting Cambrian strata has a downthrow of 285 feet on the western side. Where adequate subsurface control is available the interval between the top of the Glenwood formation and pre-St. Peter horizons in central northern Illinois shows sharp irregularities which cannot be explained by variation in the thickness of the formations, and which are attributed to post-Shakopee, pre-St. Peter deformation. Unfortunately the amount or trend of such deformation along most of the Ashton arch cannot be estimated because (1) the deeply incised pre-St. Peter drainage system makes the base of the St. Peter valueless for structural control, and (2) erosion has stripped away the post-St. Peter formations.

REFERENCES

Bays. C. A. and Others (1945), Groundwater geology of northeastern Illinois: Illinois Geol. Survey, unpublished manuscript.

Bevan, A. C. (1929), Fault block of Cambrian strata in northern Illinois (abstract): Geol. Soc. Amer. Bull. 40, p. 88.

——— (1935), Cambrian inlier at Oregon, Illinois: Kansas Geol. Soc. Guidebook 9th Ann. Field Conf., pp. 383-385.

——— (1939), Cambrian inlier in northern Illinois: Am. Assoc. Petr. Geol. Bull. 23, pp. 1561-1564.

Branson, E. B. (1944), Geology of Missouri: Univ. of Missouri Studies, vol. 19, no. 3.

Cady, G. H. (1919), Geology and mineral resources of the Hennepin and LaSalle quadrangles: Illinois Geol. Survey Bull. 37.

——— (1920), Structure of the LaSalle anticline: Illinois Geol. Survey Bull. 36, pp. 85-180.

Cohee, G. V. (1945), Sections and maps of Cambrian and Lower Ordovician rocks in the Michigan basin, Michigan and adjoining areas: U. S. Geol. Survey, Oil and Gas Inv., Prelim. Chart 9.

——— (1948), Cambrian and Ordovician rocks in Michigan basin and adjoining areas: Am. Assoc. Petr. Geol. Bull. 32, pp. 1417-1448.

Ekblaw, G. E. (1938), Kankakee arch in Illinois: Geol. Soc. Am. Bull. 49, pp. 1425-1430; Illinois Geol. Survey Cir. 40.

Horberg, C. L., (1946), Pre-glacial erosion surfaces in Illinois: Illinois Geol. Survey Rept. Inv. 118, fig. 2.

Knappen, R. S. (1926), Geology and mineral resources of the Dixon quadrangle: Illinois Geol. Survey Bull. 49.

Meyer, M. P. (1948), Pre-St. Peter structure and topography of northern Illinois: Illinois Geol. Survey, unpublished manuscript.

Payne, J. N. (1939), The age of the LaSalle anticline: Illinois Acad. Sci. Trans., vol. 31, pp. 182-183.

Pirtle, G. W., (1932), Michigan structural basin and its relationship to surrounding areas: Am. Assoc. Petr. Geol. Bull. 16, pp. 145-152.

Powell, L. H. (1935), A study of the Ozarkian faunas of southeastern Minnesota: St. Paul Inst. Sci. Mus. Bull. 1.

Twenhofel, W. H., Raasch, G. O., and Thwaites, F. T. (1935), Cambrian strata of Wisconsin: Geol. Soc. Amer. Bull. 46, pp. 1687-1744.

Ulrich, E. O., Foerste, A. F., and Bridge, Josiah (1930), Systematic paleontology of late Cambrian and early Ordovician formations of Ozark region, Missouri: Missouri Bur. Geol. and Mines, 2d ser. vol. 24, pp. 186-222.

Weller, J. M. and Others (1945), Geologic map of Illinois: Illinois Geol. Survey.

Willman, H. B. and Payne, J. N. (1942), Geology and mineral resources of the Marseilles, Ottawa, and Streator quadrangles: Illinois Geol. Survey Bull. 66.

——— (1943), Early Ordovician strata along Fox River in northern Illinois: Jour. Geol., vol. 51, pp. 531-541; Illinois Geol. Survey Circular 100.

Workman, L. E. and Bell, A. H. (1948), Deep drilling and deeper oil possibilities in Illinois: Am. Assoc. Petr. Geol. Bull. 32, pp. 2041-2062; Illinois Geol. Survey Rept. Inv. 139.

BARITE IN THE LASALLE LIMESTONE OF ILLINOIS*

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Many strata in the LaSalle limestone contain quartz, pyrite, and vugs of crystalline calcite in relative abundance. To date, however, the presence of barite has not been reported. This paper discusses and describes an occurrence of this mineral.

The barite was found in the upper part of the LaSalle limestone near the top of the limestone exposed in the abandoned LaSalle Stone Company quarry near LaSalle, in the SW¼ SW¼ NE¼ sec. 13, T.33 N. R.1 E. and also in another quarry adjacent on the west. The mineral is easily distinguished in hand specimens of the limestone by its light pink color. It occurs in small masses of thin blades, or sheets, which are easily separated with the fingernail.

The barite was identified by blow pipe and optical mineralogy techniques which were confirmed by x-ray analyses.[1] Indices of refraction check well with those commonly reported for barite. A series of specific gravity determinations with a Jolly balance averaged 4.151. This value is lower than the commonly reported gravity, but may be due to porosity resulting from the bladed character of the mineral.

Figure 1 shows a broken surface through the interior of a calcite- and barite-filled cavity. The light area in the center is the barite. Surrounding the barite is a zone of coarsely crystalline dark calcite which owes its color to a very thin coating, believed to be ferruginous. The triangular shape of many of the grains results from the exposure of only three faces of rhombic crystals. Some dark calcite grains are also evident adhering to the main body of the barite.

Figure 2 is another cavity which has been sawed, smoothed and etched with hydrochloric acid to bring the barite into relief. The white-appearing barite in the center of the figure is partially surrounded by dark, coarsely crystalline calcite which blends into more finely crystalline clear calcite. The outline of the barite, however, is well defined and conforms to the outline of the coarse calcite crystals. The mottled area in the lower right-hand portion of the photograph is limestone matrix.

Figure 3 is a thin section of a portion of a filled cavity. The cavity wall shown in the figure is part of a fossil or fossils. Just inside the cavity wall in the upper right a very thin zone of fine calcite is indistinctly visible. Radiating from the finely crystalline calcite is a layer of coarse calcite. A large calcite crystal is visible in the lower left of the photograph. The barite fills the space within the coarse calcite zone, and does not show crystal boundaries, but is in part characterized by a lack of evident crystallinity and faint striations running from upper left to lower right which result from its bladed structure. The conforming

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[1] Bradley, W. F., personal communication, 1951.

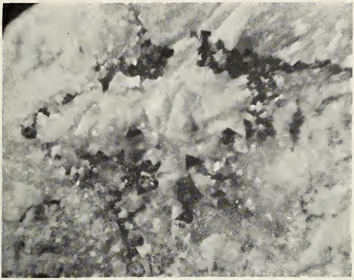

FIG. 1.—Broken surface of a small cavity filled with barite and lined with dark calcite. X 10.

FIG. 2.—Smoothed and etched surface of a barite-filled cavity. X 10.

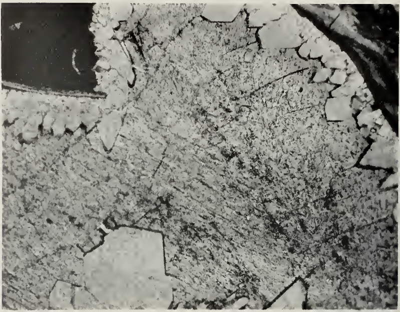

FIG. 3.—Section of a portion of a cavity lined with coarse calcite and filled with barite. X 20.

contact of the barite and the coarse calcite crystals is marked by relatively dark lines caused by the coating on the calcite previously mentioned.

The figures show two and possibly three stages of cavity filling. During the first the clear calcite of relatively small crystal size was formed on the cavity walls, followed by coarser and more euhedral crystalline calcite which appears dark. Lack of a clearly defined line between the two calcites suggests continuous deposition with conditions in the latter stage favoring the growth of larger and more perfect crystals. Subsequent to their complete growth the coarse calcite crystals have been coated with a thin brown to light-brown coating thought to be ferruginous. In some cavities this stage is absent, and the phenomenon is a local one. The barite postdates all other stages. This is indicated by the well-defined contact between the barite and the dark coarse calcite shown in figures 2 and 3, and is further borne out by the fact that some cavities contain the fine and coarsely crystalline calcite in varying amounts, but are devoid of any barite. The presence of a few calcite crystals attached to or within the barite, figures 1 and 3, might be interpreted to mean contemporaneous or penecontemporaneous deposition of the two minerals, but it is believed more likely that the calcite crystals projected from a portion of the cavity wall destroyed during preparation of the specimens for study.

REVISION OF CROIXAN DIKELOCEPHALIDS*

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The trilobites under consideration are classic in that before 1914 all species then known were assigned to the genus *Dikelocephalus,* Owen, 1852, which genus was regarded as the principal index fossil for the Upper Cambrian of the Pacific realm.

Today these same trilobites are consciously ignored by biostratigraphers. This change dates from the early 1930's, when Ulrich and Resser published their monographic revision of the Upper Mississippi Valley Dikelocephalidae (Milwaukee Public Museum Bull., vol. 12, nos. 1 and 2, 1930 and 1933).

Before 1914, less than a dozen species of *Dikelocephalus* were recognized as occurring in Upper Mississippi Valley strata. That year Walcott's paper reduced the scope of the genus by adding several new genera, as well as several new species to his ''Dikelocephalinae.''

By 1933, Ulrich and Resser had multiplied this conservative figure to the astounding total of 123 species and varieties. They simultaneously succeeded in rendering the Dikelocephalidae useless for purposes either of biostratigraphy or phylogeny, and this important fossil group has subsequently been shunned by paleontologists and stratigraphers.

The primary intent of the present paper is the restoration of the Dikelocephalidae to a useful status. This has involved a reduction of names from Ulrich and Resser's 123 to 41, or by exactly two-thirds, thus eliminating 82 names. Such a revision is of course tentative, but is quite representative of the degree of species designation that the situation merits.

Consideration of Stratigraphic Assignments

A secondary objective is assignment of the species to their proper places in the fauni-stratigraphic succession. This is necessitated because Ulrich's conception of the regional stratigraphic relations was at serious variance with the facts. Since these erroneous stratigraphic considerations seriously affected Ulrich and Resser's taxonomic conclusions, the results were unfortunate.

For example, what is now considered a single sequence, the Franconia formation, Ulrich formerly interpreted as three successive formations. He applied the name Franconia to the greensand facies occurring in the region of the Mississippi. To the equivalent non-glauconitic sandstone facies in central Wisconsin he applied the name Mazomanie. To a shore facies of the same, he applied the term Devils Lake formation. He interpreted the Mazomanie as successive to the Franconia and the Devils Lake as

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successive to both, in fact post-Cambrian. Thus the phylogenetic succession of Franconian dikelocephalids is thrice repeated.

The Trempealeau formation, which succeeds the Franconia, he conceived as a simple lithologic succession of basal dolomite (his St. Lawrence), siltstone (his Lodi), fine sandstone (his Norwalk). All fossils, therefore, that occurred in siltstone he considered to be "Lodi" in age, and all in sandstone to be "Norwalk."

The fact is that Lodi siltstone lithology occurs at eight different time-stratigraphic horizons and Norwalk sandstone lithology at six different horizons. Not only does the same lithology occur at a number of different stratigraphic horizons, but the same stratigraphic horizon is commonly represented by different lithologies in different areas. In these cases there is commonly a double set of names for each species, one for the supposed "Lodi" and one for the supposed "Norwalk."

Some of the authors' stratigraphic misconceptions have interesting results. For example, the rich faunas from leached calcareous fine sandstones at Osceola, Wis., are considered to be the latest of Trempealeau faunas; they are in fact, the earliest.

Another unfortunate result of the stratigraphic confusion was the application of some singularly inappropriate specific names. *Dikelocephalus norwalkensis, Saukiella norwalkensis,* and *Tellerina norwalkensis* do not occur in the Norwalk, nor does *Osceolia lodensis* occur in the Lodi. Fortunately, all drop into the synonymy.

CONSIDERATION OF TAXONOMIC CRITERIA

A third objective of the present paper is to present a concrete instance of the effect, on taxonomic results, of differing species concepts among different paleontologists. Once we leave the realm of living forms, the species concept is no longer subject to the restraint of genetic criteria. Inevitably, individual paleontologists resort to their own methodology in grouping organisms into species, genera, and higher categories. The only test against which the quality of any worker's results may be applied is the pragmatic one of applicability of his biologic classification in the fields of biostratigraphy and of phylogeny. If the classification contributes to order it may be assumed to be valid; if it contributes to confusion it may with equal justice be assumed to be invalid. The responsibility demanded of the paleontologist is accordingly great.

From this viewpoint it follows logically that paleontologic studies must go hand in hand with stratigraphic studies. But erroneous stratigraphy renders confusion twice confounded.

In the case of Ulrich and Resser's work in the Dikelocephalinae, the following practices and concepts have contributed to confused taxonomy:

(1) Basing of species on type individuals rather than on populations.

(2) Seeking for minute differences rather than for likenesses.

(3) Misassociation of the various, separated component parts of the skeleton, commonly combining a cranidium from one locality, a pygidium from a second, and free cheeks from a third.

(4) Failure to consider that variations may be a result of successive growth stages.

(5) Rejection of any concept of individual variation.

(6) The influence of stratigraphic misconceptions.

(7) Rejection of trinomial classification for varieties or subspecies.

(8) Establishment of species on inadequate material.

Basing of species on type individuals rather than on populations.—Under discussion of *Calvinella spiniger,* on page 222, the authors state:

> However, we will admit at once that in studying the many slightly differing cranidia of *Calvinella* that we possess *from the same bed and place* [italics the writer's] on Trempealeau Mountain that provided Hall's original type of the species, we found it no easy task to determine precisely which particular kind is best entitled to the distinction of being recognized as the typical form of *C. spiniger*. Though our final selection is not entirely satisfactory to us we are so nearly correct that the margin of error is practically negligible. . . .
>
> The remainder of the specimens of *Calvinella* that were found with *C. spiniger*, as here restricted, is divided into seven varieties and species.

The series is clearly intergrading and in this writer's opinion, constituted a single interbreeding species population of distinct zonal value.

Seeking for minute differences rather than for likes.—An example of proliferation of species by Ulrich and Resser is provided by the *Prosaukia* occurrence at Table Rock in Adams County, Wis. The fauna here comes from a six-inch layer about a foot below the bare rock summit of the mesa, the area of which is less than an acre. From this layer, Ulrich and Resser describe eight species of *Prosaukia,* all but one of which appear to constitute a single species. The eighth, *P.* ? *anomala,* belongs to another genus, not of the Dikelocephalidae. Most of the "species" the authors credit to the type locality only. Quoting from p. 146:

> All of the . . . species found at the Table Rock locality, except *P.*? *anomala*, seem very closely related. Their cranidia, in particular, though distinguishable by features that may seem of little importance, are much alike. The associated pygidia, on the contrary, indicate six readily discriminated forms, and on this account the species are based mainly on these. Cranidia, and in most cases also free cheeks, are assigned to them according to our best judgment.

Actually none of their pygidia are complete, most are highly fragmentary, and in the writer's opinion show no significant differences.

In connection with one of Ulrich and Resser's species, "*P. alternata,*" these authors frankly state:

> Again the material, which consists of a single cranidium, a good free cheek, and three imperfect but supplementing pygidia, leaves much to be desired. But as none of these specimens quite fits any of the previously described species and, despite their imperfections, permits acquiring . . . probably a true conception of the complete animal, we feel warranted . . . in describing these and other combinations of such dismembered remains under new names.

Misassociation of the various component parts of the skeleton.—Many examples might be cited, but the following should suffice:

Dikelocephalus inaequalis is based on three types from the basal Jordan at Trempealeau, Wis., but the fourth type (an hypostoma) comes from the basal Trempealeau (five zonal units lower in the section) at a distant locality. Its proper association should have been with quite a different species, *D. thwaitesi.* The writers, of course, were of the impression that the enclosing strata at the two localities were of the same age.

Failure to consider that variations may be a result of successive growth stages.—Ulrich and Resser's multiplication of species of *Dikelocephalus* from the Lodi Member is a consequence largely of failure to recognize morphological changes which accompany growth stages. Ulrich and Resser cite (p. 31), but do not figure, evidence to refute this, but such evidence this writer has never observed although he collected most of the specimens used by them. He feels that at least four of their Lodi species are successive growth stages of a single species. Since most specimens are molts, it was quite possible for a single individual to produce four of Ulrich and Resser's species.

Rejection of any concept of individual variation.—This point is best illustrated by an oral communication of the junior author to the writer. When the latter raised the question as to whether some of the differences among specimens of *Dikelocephalus* might not represent individual variation, Resser categorically stated that "trilobites do not vary. If two specimens are different, they represent different species."

The influence of stratigraphic misconceptions. — Instances are innumerable and lead the authors repeatedly into frustrating phylogenetic discussions, in an attempt to rationalize seeming anomalies.

The degree of stratigraphic error might best be summed up by citing the fact that, of the 473 figures used to illustrate the Saukinae, at least 290 are referred to the wrong stratigraphic horizon.

Rejection of trinomial classification.—The authors' proliferation of species is in part a result of the fact that they discriminated, according to their criteria, down to the variety or subspecies level and then usually omitted the middle or species name. This is borne out by such printed statements as the following:

> However, in general we are opposed to trinomial designations. [p. 206.]
>
> It is of little concern to us whether these forms are regarded as "species" or "varieties," or "mutations" or "hybrids." [p. 170.]

Establishment of species on inadequate material.—That many species were set up by the writers on a single fragmentary cranidium, pygidium, or free cheek is readily evident from even a casual inspection of the plates.

Revision of the Family Dikelocephalidae

Inasmuch as the family Dikelocephalidae, as conceived by Miller (1889), Walcott (1914), and Ulrich and Resser (1930), is revealed by unpublished studies of the writer to be polyphyletic, it is proposed that Ulrich and Resser's (1930) Saukinae be raised to a separate family, the Saukidae. Biostratigraphic studies show that the Saukinae arise from the mid-Franconian Ptychaspidae, which are descended in turn from early Franconian conaspid trilobites. The latter appear to arise directly from Old World *Parabolina,* present in the Upper Mississippi Valley section in the base of the *Conaspis* zone. The Dikelocephalinae (including the Osceolinae), on the other hand, appear to have descended through the late mid-Franconian *Briscoia*, from the earlier Franconian genus *Wilbernia*. The writer also questions the need for the subfamily Osceolinae, comprising the genera *Walcottaspis* and *Osceolia*. *Walcottaspis* appears to be merely a descendant of *Dikelocephalus*, whereas *Osceolia* is an early Trempealeauan, probably terminal offshoot of *Briscoia*.

REVISION OF THE "DIKELOCEPHALINAE"

Ulrich and Resser's, 1930, Dikelocephalinae, comprising 36 species of the genera *Dikelocephalus*, *Briscoia*, *Osceolia*, and *Walcottaspis*, are reduced by the writer to a status of 12 species, as indicated in the following presentation, in ascending biostratigraphic order:

FRANCONIA

- Hudson member–*Prosaukia curvicostata* faunal unit
  - *Briscoia schucherti* U & R
- Hudson member–*Briscoia sinclairensis* faunal unit
  - *Briscoia sinclairensis* Walcott
  - Note: referred by Ulrich and Resser (1930—p. 59) to the "Lower Ozarkian, Devils Lake Formation," but actually occurring late in the *Prosaukia* subzone of the Franconia, Hudson member.
- Bad Axe member–*Saukiella minor* faunal unit
  - *Dikelocephalus postrectus* U & R

TREMPEALEAU

- Arcadia member–*Osceolia osceola* faunal unit
  - *Osceolia osceola* (Hall)
  - Synonyms: *O. obsoleta* U & R, *O. arguta* U & R, *O. lodensis reflexa* U & R, *O. praecipta* U & R
  - *Dikelocephalus thwaitesi* U & R
  - Synonyms: *D. weidmani* U & R, *D. halli* U & R, *D. inaequalis* U & R, *pars* (pl. 19, fig. 6)
  - Note: *D. thwaitesi* of pl. 21, figs. 7-10 is *D. oweni* U & R.
- Lodi member–*Saukia subrecta* faunal unit
  - *Dikelocephalus (oweni* var.?) *barretti* U & R
  - Synonyms: *D. brevis* U & R (except pl. 14, fig. 2), *D. edwardsi* U & R, *D. subplanus pars* (pl. 14, figs. 3, 5), "*D.* cf. *gracilis* and *retrorus*" (pl. 14, fig. 9)
  - *D. norwalkensis* U & R (except pl. 21, figs. 19, 20)
- Lodi member–*Saukia sublonga* faunal unit
  - *Dikelocephalus oweni* U & R
  - Synonyms: *D. gracilis* U & R, *D. ovatus* U & R, *D. wisconsinensis* U & R, *D. subplanus* U & R, *D. retrorsus* U & R, *D. beani* U & R, *D. raaschi* U & R (pl. 10, fig. 1 may be a distinct variety), *D. brevis pars* (pl. 9, fig. 5?), *D. marginatus pars* (pl. 15, figs. 6, 7), *D. thwaitesi pars* (pl. 21, figs. 7 to 10), *D. norwalkensis pars* (pl. 21, figs. 19, 20)

  There is some doubt as to the proper reference of the specimen, fig. 6, pl. 9, designated as *D. gracilis* by Ulrich and Resser.

  Note: There is admittedly considerable variation evident among the various parts of the dorsal shields of *Dikelocephalus* occurring in the Lodi member. Much of this seems to be a matter of the age or stage of the molt, which doubtless most of the specimens represent. On this basis the *Saukia sublonga* zonal unit material seems to group itself as follows:

  1. Small pustulose forms, with palpebral lobes close to parallel with longitudinal axis, and relatively posterior in position. Pygidia with five pairs of equal pleural ribs and long slender postlateral spines.
  2. Medium-sized forms, generally not pustulose, with palpebral lobes intermediate between those of groups 1 and 3 in orientation and position. Pygidia averaging four pairs of subequal pleural ribs, with more triangular spines.

3. Large forms with palpebral lobes relatively far forward and oriented to anterior convergence. Pygidia averaging 3½ pairs of pleural ribs, alternatingly wide and narrow; pygidial spines short and basally broad.

The *Dikelocephalus* of the underlying *Saukia subrecta* unit is not greatly different from the *S. sublonga* species except that the more juvenile characters of slender spines and of pustulation seem to persist in individuals of medium size.

Lodi member–*Saukia lodensis* faunal unit

Dikelocephalus minnesotensis Owen
Synonyms: *D. hotchkissi* U & R, *D. intermedius* U & R, *D. granosus* U & R, *D. wiltonensis* U & R, "*D.* cf. *orbiculatus*" U & R (pl. 17, fig. 1), *D. brevis pars* (pl. 14, fig. 2). Probably also *D. orbiculatus* U & R, and *Briscoia?* sp. (pl. 17, fig. 10)
Note: As in the immediately ancestral *D. oweni* group of forms, young individuals are granulose (cf. *D. granosus* U & R, above). The *D. minnesotensis* group differs from the *D. oweni* group particularly in possessing a more expanded frontal limb and a narrower and more elliptical pygidium with subequal ribs even in the largest specimens.

Jordan member–*Calvinella wisconsinensis* faunal unit

Dikelocephalus marginatus U & R (except pl. 15, figs. 6 and 7)
Synonym: *D. declivis* U & R

Jordan member–*Calvinella pustulosa* faunal unit

Dikelocephalus marginatus U & R (as above)
Dikelocephalus inaequalis U & R (except pl. 19, fig. 6)
Note: *D. juvenalis* U & R of this zone is not recognized, being most probably the very young of the above.

Jordan member—*Saukiella pepinensis* faunal unit

Dikelocephalus marginatus U & R

Jordan member–*Walcottaspis vanhornei* faunal unit

Walcottaspis vanhornei (Walcott).
Note: The true position of this species in the Trempealeau faunal succession was pointed out to the writer by W. C. Bell and R. Berg in connection with its occurrence near Reno, Minnesota.

Dikelocephalid fragments occurring higher, in the Madison, may represent *Walcottaspis* rather than *Dikelocephalus*, but generically identifiable material has not yet been obtained.

Revision of the Saukinae

Simple synonymic cross references do not suffice, in the case of the Saukinae revision, to indicate proposed revised nomenclature. This is because many of Ulrich and Resser's (1933) species not only appear to be synonyms, but the illustrated material which they figure as one species from one stratigraphic horizon commonly must be distributed among several species and several stratigraphic horizons. Accordingly, in many cases it has been necessary to make reassignments, both taxonomic and stratigraphic, on the basis of individual plate figures. Stratigraphic references cited below are those of the writer, not of Ulrich and Resser.

Plate 24.

Figs. 1-9. *Prosaukia misa* (Hall) =*P. misa* (Hall)
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*misa* facies).

Figs. 10-13. *Prosaukia resupinata* U & R=*P. misa* (Hall)
Same occurrence as above.

Plate 25

Figs. 1-7. *Prosaukia curvicostata* U & R
Figs. 8-12. *Prosaukia alternata* U & R
Figs. 13-16. *Prosaukia transversa* U & R
Figs. 17-18.*Prosaukia demissa* U & R
Fig. 19. *Prosaukia subconica* U & R
=*P. curvicostata* U & R

Franconia formation, *Prosaukia* subzone, *curvicostata* zonal unit.

Fig. 20. *Saukiella transita* U & R= *S. conica* U & R
Franconia formation, *Saukiella minor* zonal unit, Prairie du Sac, Wis. (Not "Gibraltar Rock, Wis.")

PLATE 26.

Fig. 1. *Prosaukia concava* U & R= *P. misa* U & R
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*misa* facies).

Figs. 2-8. *Prosaukia subrecta* U & R
Figs. 9-12. *Prosaukia subaequalis* U & R
=*P. curvicostata* U & R
Franconia formation, *Prosaukia* subzone, *curvicostata* zonal unit.

Figs. 13-17. *Prosaukia delecostata* U & R=*P. delecostata* U & R
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit.

PLATE 27.

Figs. 1-2. *Prosaukia longa* U & R= *P. longa* U & R
Franconia formation, *Prosaukia* subzone, *Briscoia sinclairensis* zonal unit.

Figs. 3-9. *Prosaukia halli* U & R= *P. halli* U & R
Franconia formation, *Prosaukia* subzone, *P. misa—longicornis* zonal unit (*P. misa* facies).

Figs. 10-11. *Prosaukia brevisulcata* U & R=*P. longicornis* var. *brevisulcata* (U & R)
Franconia formation, *Prosaukia* subzone, *P. misa—longicornis* zonal unit (*longicornis* facies)

Figs. 12-21. *Prosaukia longicornis* U & R=*P. longicornis* U & R
Occurrence same as preceding.

Figs. 22-25. *Prosaukia ampla* U & R= *P. ampla* U & R
Franconia formation, *Saukiella minor* zonal unit.

PLATE 28

Figs. 1-2,4. *Prosaukia magnicornuta* U & R=*P. longicornis* U & R
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*longicornis* facies)

Fig. 3. *Prosaukia magnicornuta* U & R =*P. l.* var. *brevisulcata* (U & R)
Occurrence same as preceding.

Fig. 5. *Prosaukia tuberculata* U & R= *P. tuberculata* U & R
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*longicornis* facies).

Figs. 6-7. *Prosaukia longula* U & R= *P. tuberculata* U & R
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*longicornis* facies).

Fig. 8. *Prosaukia valida* U & R=*P. valida* U & R
Franconia formation, *Prosaukia* zone, zonal unit undetermined.

Fig. 9. *Prosaukia lodensis* U & R= *Saukia* cf. *curvata* U & R
Trempealeau formation, Lodi member, *S. subrecta* zonal unit.

Figs. 10-11. *Prosaukia* sp. undet.= *Saukia subrecta* U & R
Trempealeau formation, Lodi member, *S. subrecta* zonal unit.

Figs. 12-17. *Prosaukia incerta* U & R= *Saukiella* (?) *incerta* (U & R)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit (sandstone facies).

Fig. 18. *Prosaukia granosa* U & R= *P. beani* U & R
Franconia formation, Hudson member.

Fig. 19. *Prosaukia berlinensis* U & R: validity undetermined
Exact stratigraphic position undetermined.

Fig. 20. *Prosaukia dubia* U & R=*P. beani* U & R
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*longicornis* facies).

Fig. 21. *Prosaukia beani* U & R=*P. beani* U & R
Occurrence same as preceding.

PLATE 29

Figs. 1-3. *Prosaukia* (?) *anomala* U & R: not a Prosaukia, but belongs to an undescribed, non-saukid genus
Franconia formation, *Prosaukia* subzone, *curvicostata* zonal unit.

Figs. 4-6. *Saukia obtusa* U & R=*S. acuta* U & R
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.

Fig. 7. *Saukia sublonga* U & R=*S. sublonga* U & R
Trempealeau formation, Lodi member, *S. sublonga* zonal unit.

Fig. 8. *Saukia angusta* U & R=*S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.

Figs. 9-10. *Saukia modesta* U & R= *S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.

Fig. 11. *Saukia rudis hybrida* U & R cf. *S. acuta* U & R
Trempealeau formation, Lodi member, *S. lodensis* zonal unit (sandstone facies).

Figs. 12-13. *Saukia whitfieldi* U & R= *S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.

Fig. 14. *Saukia whitfieldi* U & R=*S. acuta* U & R
Occurrence same as preceding.

Figs. 16-17. *Saukia acuta* U & R=*S. acuta* U & R
Occurrence same as preceding.

Fig. 18. *Saukia* cf. *whitfieldi* U & R= *S. subrecta* U & R
Trempealeau formation, Lodi member, *S. subrecta* zonal unit.

Fig. 19. *Saukia subrecta* U & R=*S. subrecta* U & R
Occurrence same as preceding.

Fig. 20. *Saukia subrecta* U & R=undetermined trilobite, cf. *Eurekia*
Occurrence same as preceding.

PLATE 30

Figs. 1-2. *Saukia nitida* U & R=*S. subrecta* U & R
Trempealeau formation, Lodi member, *S. subrecta* zonal unit.

Fig. 3. *Saukia ornata* U & R=*S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.

Fig. 4. *Saukia ornata* U & R=undetermined trilobite cf. *Eurekia.*
Trempealeau formation, Lodi member.

Fig. 5. *Saukia curvata* U & R=*S. curvata* U & R
Trempealeau formation, Lodi member, *S. subrecta* zonal unit.

Fig. 6. *Saukia laevigenata* U & R= *S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.

Fig. 7. *Saukia subgranosa* U & R=*S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.

Figs. 8-10. *Saukia separatoidea* U & R =*S. subrecta* U & R
Trempealeau formation, Lodi member, *S. subrecta* zonal unit.

Figs. 11-12. *Saukia tumida* U & R: not recognized; material inadequate.
Trempealeau formation, Lodi member, *S. lodensis* zonal unit (sandstone facies).

Figs. 13-16. *Saukia retusa* U & R=*S. acuta* U & R
Occurrence same as preceding.

Figs. 17-25. *Saukia rudis* U & R=*S. lodensis* (Whitfield)
Occurrence same as preceding.

Fig. 26. *Saukia parva* U & R=*S. acuta* U & R
Trempealeau formation; exact zonal occurrence not known.

PLATE 31.

Figs. 1-5. *Prosaukia acclivis* U & R= *P. halli* var. *acclivis* (U & R)
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*misa* facies).

Figs. 6-8. *Prosaukia* (?) *ambigua* U & R=undescribed genus aff. *Taenicephalus*
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*misa* facies, late stage).

Figs. 9-10a. *Saukia prima* U & R= *Prosaukia* (?) *dilata* U & R
Stratigraphic occurrence uncertain.

Fig. 11. *Saukia granilineata* U & R: not recognized
Trempealeau formation, Lodi member, *Saukia subrecta* zonal unit.

Figs. 12-13. *Prosaukia minuscula* U & R=*P. halli* var. *acclivis* (U & R)
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*misa* facies, late stage).

Figs. 14-20. *Saukia separata* U & R= *S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit (sandstone facies).

Figs. 21-25. *Saukia imperatrix* U & R =*S. imperatrix* U & R
Trempealeau formation, exact stratigraphic occurrence undetermined.

Fig. 26. *Saukia lodensis* (Whitfield): relation undetermined; preservation inadequate
Trempealeau formation, Lodi member, *S. sublonga* zonal unit.

Fig. 27. *Saukia lodensis* (Whitfield)= *S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.

Figs. 28-31. *Prosaukia dilata* U & R= *P. dilata* U & R
Stratigraphic occurrence uncertain.

PLATES 32 and 33.

All specimens figured are conspecific with *Saukiella pepinensis* Owen and accordingly the following names may be considered synonyms:

Saukiella typicalis
Saukiella typicalis convexa
Saukiella typicalis subrecta
Saukiella subgracilis

Saukiella subgracilis hybrida
Saukiella subgracilis parallela
Saukiella ampla

The occurrence is not from the Lodi shale, as the authors state, but from the *Saukiella pepinensis* zonal unit of the overlying Jordan member of the Trempealeau formation.

PLATE 34

Saukiella pyrene (Walcott)=*Saukiella pyrene* (Walcott)
Trempealeau formation, Arcadia member, *Osceolia osceola* zonal unit.

PLATE 35.

Figs. 1-8. *Saukiella pyrene* (Walcott) =*S. pyrene* (Walcott)
Trempealeau formation, Arcadia member, *Osceolia osceola* zonal unit.

Fig. 9. *Saukiella* cf. *pyrene*=*S. pyrene* (Walcott)
Trempealeau formation, Lodi member, sandstone facies.

Fig. 10. *Saukiella* cf. *pyrene*=*S. minor* U & R
Franconia formation, Bad Axe member, *Saukiella minor* zonal unit.

Fig. 11. *Saukiella* cf. *pyrene*=*S. indenta* U & R
Trempealeau formation, Lodi member, *Saukia lodensis* zonal unit (sandstone facies).

Figs. 12-14. *Saukiella pyrene limbata* U & R=*S. indenta* U & R
Trempealeau formation, Lodi member, *Saukia sublonga* zonal unit (sandstone facies).

Figs. 15-21. *Saukiella signata* U & R= *S. pyrene* (Walcott)
Trempealeau formation, Arcadia member, *Osceolia osceola* zonal unit.

Fig. 22. *Saukiella frontalis* U & R= *Saukiella frontalis* U & R
Trempealeau formation, Jordan member, Norwalk sandstone, *Saukiella frontalis* zonal unit.

Figs. 23-25. *Saukiella indenta* U & R =*S. indenta* U & R
Trempealeau formation, Lodi member, *Saukia sublonga* zonal unit (sandstone facies).

Figs. 26-30. *Saukiella indenta* U & R =*Saukiella frontalis* U & R
Trempealeau formation, Jordan member, Norwalk sandstone, *Saukiella frontalis* zonal unit.

PLATE 36.

Figs. 1-3. *Saukiella indenta* U & R= *S. indenta* U & R
Trempealeau formation, Lodi member, *Saukia lodensis* zonal unit (sandstone facies).

Fig. 4. *Saukiella indenta intermedia* U & R=*S. indenta* U & R
Trempealeau formation, Lodi member, sandstone facies.

Figs. 5-11. *Saukiella norwalkensis* U & R=*Saukiella pyrene* (Walcott)
Trempealeau formation, Arcadia member, *Osceolia osceola* zonal unit.

Figs. 12-14. *Saukiella norwalkensis* U & R=*S. indenta* U & R
Trempealeau formation, Lodi member, *S. sublonga* zonal unit (sandstone facies).

Figs. 15-25. *Saukiella norwalkensis* U & R=*S. pyrene* (Walcott)
Trempealeau formation, Arcadia member, *Osceolia osceola* zonal unit.

Figs. 26-27. *Saukiella norwalkensis* U & R=*S. indenta* U & R
Trempealeau formation, Lodi member, *S. sublonga* zonal unit (sandstone facies).

Figs. 28-30. *Saukiella simplex* U & R= *S. minor* U & R
Franconia formation, Bad Axe member, *Saukiella minor* zonal unit.

Figs. 31-32. *Saukiella* (?) *weidmani* U & R=*Tellerina? leucosia* (Walcott) Trempealeau formation, Arcadia member, *Osceolia osceola* zonal unit.

PLATE 37.

Figs. 1-5. *Saukiella conica* U & R= *S. minor* U & R
Franconia formation, Bad Axe member, *Saukiella minor* zonal unit.

Figs. 6-17. *Saukiella minor* U & R= *S. minor* U & R
Same occurrence as preceding.

Figs. 18-29. *Calvinella spiniger* (Hall) =*C. spiniger* (Hall)
Trempealeau formation, Jordan member, *C. spiniger* zonal unit.

Figs. 30-35. *Tellerina granistriata* U & R=*T. granistriata* U & R
Trempealeau formation, Lodi member, exact zonal position undetermined.

PLATE 38.

All specimens figured are conspecific with *Calvinella spiniger* (Hall), and, coming all from the same stratum at the same locality, represent the range of variation of a single species population. Accordingly, the following names, appearing on the explanation of plate 38, may be considered as synonyms:

Calvinella spiniger altimuralis U & R
Calvinella spiniger communis U & R
Calicinella spiniger communis mutation U & R

Calvinella spiniger postlevata U & R
Calvinella clivula U & R
Calvinella spiniger (Hall) ? (of U & R)
Occurrence: Trempealeau formation, Jordan member, *Calvinella spiniger* zonal unit, which the writer believes to lie at the base of the Jordan, below siltstone bearing the *Calvinella wisconsinensis* fauna.

PLATE 39.

Figs. 1-10. *Calvinella pustulosa* U & R =*Calvinella pustulosa* U & R
Trempealeau formation, Jordan member, *C. pustulosa* zonal unit.
Figs. 11-16. *Calvinella sparsinodata* U & R=cf. *Calvinella spiniger* (Hall)
Trempealeau formation, Jordan member, *C. spiniger* zonal unit.
Figs. 17-18. *Calvinella pustulosa vernonensis* U & R=*Calvinella pustulosa* U & R
Trempealeau formation, Jordan member, *C. pustulosa* zonal unit.
Figs. 19-24. *Calvinella notata* U & R=*Calvinella walcotti* U & R
Trempealeau formation, Jordan member, zonal unit undetermined.
Figs. 25-30. *Calvinella lata* U & R=*Calvinella walcotti* U & R
Occurrence same as preceding.
Figs. 31-34. *Calvinella walcotti norwalkensis* U & R=*Calvinella spiniger* (Hall)
Trempealeau formation, Jordan member, *C. spiniger* zonal unit.
Figs. 35-36. *Calvinella wisconsinensis junior* U & R=*Calvinella spiniger* (Hall)
Occurrence same as preceding.

PLATE 40.

Figs. 1-14. *Calvinella walcotti* U & R=*C. walcotti* U & R
Trempealeau formation, Jordan member, exact zonal position undetermined.
Figs. 15-22. *Calvinella walcotti planulata* U & R=*C. walcotti* U & R
Occurrence same as above.
Figs. 23-33. *Calvinella wisconsinensis* U & R=*C. wisconsinensis* U & R
Trempealeau formation, Jordan member, *Calvinella wisconsinensis* zonal unit.
Fig. 34. *Calvinella walcotti* ? U & R: cf. *C. walcotti* U & R
Fig. 35. *Calvinella notata* ? U & R: cf. *C. wisconsinensis* U & R
Figs. 36-39. *Calvinella walcotti* ? U & R=*C. walcotti* U & R
Trempealeau formation, Jordan member, exact zonal position undetermined.

PLATE 41

Figs. 1-9. *Tellerina crassimarginata* (Whitfield)=*T. crassimarginata* (W.)
Trempealeau formation, Lodi member, *Saukia sublonga* zonal unit.

PLATE 42.

Fig. 1. *Tellerina crassimarginata* (Whitfield)=*T. crassimarginata* (W.)
Occurrence same as above.
Figs. 2-3. *Tellerina curta* U & R=*T. crassimarginata* (W.)
Occurrence same as preceding.
Figs. 4-5. *Tellerina gothamensis* U & R =*T. gothamensis* U & R
Trempealeau formation, Lodi member, *Saukia subrecta* zonal unit.
Fig. 6. *Tellerina bigeneris* U & R: cf. *Saukia acuta* U & R
Trempealeau fromation, Lodi member, *Saukia lodensis* zonal unit.
Fig. 7. *Tellerina strigosa* U & R=*T. crassimarginata* (W.)
Trempealeau formation, Lodi member, *Saukia sublonga* zonal unit.

PLATE 43.

Figs. 1-5. *Tellerina strigosa* U & R=*T. crassimarginata* (W.)
Occurrence same as preceding.
Fig. 6. *Tellerina lata* U & R: cf. *T. crassimarginata* (W.)
Occurrence undetermined.
Fig. 7. *Tellerina recurva* U & R=*T. crassimarginata* (W.)
Trempealeau formation, Lodi member, *Saukia sublonga* zonal unit.

PLATE 44.

All specimens figured are conspecific with *Tellerina* ? *leucosia* (Walcott), and the following names may be regarded as synonyms:
Tellerina leucosia (Walcott)
Tellerina leucosia variety
Tellerina leucosia parallela U & R
The occurrence is not the Norwalk sandstone (a member of the Jordan formation), but the basal Trempealeau, Arcadia member.

PLATE 45.

Figs. 1-10. *Tellerina extrema* U & R=*Tellerina* ? *leucosia* (Walcott)
Occurrence same as preceding plate.
Figs. 11-13. *Tellerina norwalkensis* U & R=*T. crassimarginata* (W.)

Trempealeau formation, Lodi member, *Saukia sublonga* zonal unit (sandstone facies).

Fig. 14. *Tellerina norwalkensis* U & R: not identifiable.

Figs. 15-16. *Tellerina norwalkensis* U & R=*T. crassimarginata* (W.) Trempealeau formation, Lodi member, *Saukia sublonga* zonal unit (sandstone facies).

STRATIGRAPHIC NOTE

ARCADIA MEMBER

Since the latest published account of Trempealeau stratigraphy (Raasch, 1939), an additional member of that formation has been discriminated. This member, for which the term *Arcadia* is proposed, lies beneath the basal conglomerate of the St. Lawrence member, and rests with a strong basal conglomerate upon the Franconian, Bad Axe greensands. Areally the member is evidently continuously extensive north of the Black River valley, in Wisconsin and Minnesota, but to the southward is only locally present where small remnants have escaped pre-St. Lawrence erosion. The member bears the *Osceolia osceola* faunal assemblage.

The type locality selected is a road cut and small quarry on State Highway No. 93, 1 mile south of its junction with Highway No. 95, east of Arcadia, Trempealeau County, Wisconsin. Here the persistent greensands of the Franconia, Bad Axe member, are unconformably overlain by a spectacular 3-foot bed of edgewise conglomerate, flat pebbles of buff siltstone in a greensand matrix. This bed grades upward into 17.1 feet of somewhat lenticular strata of varied lithology, dominantly dolomitic siltstone and fine, greenish gray to light brown, somewhat dolomitic sandstone. *Osceolia osceola* Hall and *Dikelocephalus thwaitesi* U & R were collected.

The Arcadia succession is overlain by the basal St. Lawrence conglomerate (with dolomitic matrix and Arcadia sandstone pebbles), succeeded by 11.2 feet of sandy dolomite.

ST. LAWRENCE MEMBER

The fauna of the St. Lawrence member continues to be designated by the term *Platycolpus,* to which the specific term *eatoni* has been added, since the range of the genus greatly exceeds the span of the member. However, as the St. Lawrence member, which seldom exceeds 20 feet in the Wisconsin-Minnesota region, attains a thickness of more than 100 feet in parts of northeastern Illinois, it may represent a complex of faunal units, in addition to the substantive one to which the term *Platycolpus eatoni* is properly applied.

LODI MEMBER

The Lodi member is characterized faunally by a succession of at least three closely related faunal units. Of these, the middle or *Saukia sublonga* faunal unit yielded most of the classic collections from the "Dikelocephalus beds." The earlier *Saukia subrecta* faunal unit occurs in a lentil of limited thickness, as yet known only from the lower Wisconsin Valley. The *Saukia lodensis* faunal unit occurs in siltstone in the upper part of the Lodi member, largely in Sauk, Columbia, and Dane counties in southern Wisconsin, but also in similar lithology at Stillwater, Minnesota. In the intervening area (in a direct line), the Lodi member passes wholly to sandstone,

Chart No. 1.—ZONAL SUCCESSION OF DIKELOCEPHALID SPECIES

	Zonal Unit	Dikelocephalidae	Associated Genera
SAUKIA ZONE	14. "Madison Fauna" unconformity	undescribed *Tellerina*, *Calvinella*, *Dikelocephalus*(?) base of Madison formation	*Plethometopus*, *Entomaspis*, *Stenopilus*, *Plethopeltis*
	13. "Van Oser Fauna"	undescribed *Saukia*, *Saukiella*, *Tellerina*	*Stenopilus*, *Euptychaspis*
	12. *Saukiella frontalis*	*Saukiella frontalis* U.& R	
	11. *Walcottaspis vanhornei*	*Walcottaspis vanhornei* (Walcott)	*Stenopilus*
	10. *Saukiella pepinensis*	*Saukiella pepinensis* (Owen) *Dikelocephalus marginatus* U & R	*Plethometopus*
	9. *Calvinella pustulosa* unconformity	*Calvinella pustulosa* U & R *Dikelocephalus inaequalis* U & R *Dikelocephalus marginatus* U & R	*Eurekia*, *Corbinia*, *Triarthropis*, *Entomaspis* *Stenopilus*, "*Agnostus disparilis*" Hall
	8. *Calvinella wisconsinensis*	*Calvinella wisconsinensis* U & R *Dikelocephalus marginatus* U & R *Tellerina* sp. nov. *Prosaukia* sp. nov.	*Eurekia*, *Corbinia*
	7. *Calvinella spiniger*[1] unconformity	*Calvinella spiniger* (Hall) base of Jordan member	*Eurekia*, *Corbinia*
	6. *Saukia lodensis*[2]	*Saukia lodensis* (Whitfield) *Saukia acuta* U & R *Tellerina crassimarginata* (Whitfield) *Saukiella ? indenta* U & R *Saukiella ? incerta* U & R *Dikelocephalus minnesotensis*	*Illaenurus*, *Eurekia*, *Corbinia*, *Plethometopus*, *Triarthropsis*, *Entomaspis*, *Euptychaspis*, *Acheilops*, "*Agnostus disparilis*"
	5. *Saukia sublonga*	*Saukia sublonga* U & R *Saukiella indenta* U & R *Tellerina crassimarginata* (Whitfield) *Dikelocephalus oweni* U & R	*Illaenurus*, *Acheilops*, *Euptychaspis*, "*Agnostus disparilis*" Hall, *Plethometopus*, *Corbinia*, *Entomaspis*, *Eurekia*, *Triarthropsis*, *Stenopilus*
	4. *Saukia subrecta* U & R base of Lodi member	*Saukia subrecta* U & R *Saukia curvata* U & R *Tellerina gothamensis* U & R *Dikelocephalus oweni* var. barretti (U & R)	*Illaenurus*
	3. *Platycolpus eatoni* (Whitfield) unconformity	undescribed *Tellerina*, *Dikelocephalus* base of St. Lawrence member	*Illaenurus*, *Eurekia*, *Plethometopus*, *Stenopilus*, *Corbinia*, *Platycopus*

SAUKIA ZONE	2. *Osceolia osceola* unconformity	*Osceolia osceola* (Hall) *Dikelocephalus thwaitesi* U & R *Saukiella pyrene* (Walcott) *Tellerina ? leucosia* (Walcott) base of Arcadia member, Trempealeau formation	*Illaenurus, Eurekia, Corbinia, Triarthropsis, Euptychaspis*
	1. *Saukiella minor* U & R unconformity?	*Saukiella minor* U & R *Prosaukia ampla* U & R *Dikelocephalus postrectus* U&R *Dikelocephalus* sp. nov. *Briscoia* sp. nov. *Calvinella* sp. nov. base of Bad Axe member, Franconia formation	*Illaenurus, Monocheilus*
PROSAUKIA SUBZONE	4. *Briscoia sinclairensis*	*Briscoia sinclairensis* *Prosaukia longa* U & R	*Platycolpus*
	3. *Briscoia* (unnamed)	*Briscoia* sp. nov. *Prosaukia* near *longa* U & R	*Platycolpus,* *Monocheilus*
	2. *Prosaukia curvicostata*	*Prosaukia curvicostata* U & R *Briscoia schucherti* U & R	
	1. *Prosaukia longicornis*	*Prosaukia misa* (Hall)[3] *Prosaukia halli* U & R[3] *Prosaukia halli acclivis* U & R[3] *Prosaukia delecostata* U & R[4] *Prosaukia longicornis* U & R *Prosaukia l. brevisulcata*[4] *Prosaukia tuberculata* U & R[4] *Briscoia* sp. nov.[4]	*Dartonaspis*[4] *Chariocephalus*[3] *Idahoia* *Ellipsocephaloides*[3] *Ptychaspis*[3] *Wilbernia*[3] *Litagnostus*[3]
	Ptychaspis subzone local unconformity	*Wilbernia*, ancestral to *Dikelocephalus* *Ptychaspis*, ancestral to *Prosaukia* base of Hudson member, Franconia formation	*Monocheilus, Psalaspis, Idahoia, Ellipsocephaloides, Litagnostus, Pseudagnostus*

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[1] Stratigraphic position not conclusively established.
[2] A central and southern Wisconsin facies.
[3] Greensand facies; *P. misa* faunal facies.
[4] Non-greensand facies; *P. longicornis* faunal facies.

in which somewhat different faunal facies of both the *Saukia sublonga* and *Saukia lodensis* faunal units have tentatively been identified.

JORDAN MEMBER

In western Wisconsin, conglomeratic and dolomitic strata marking the base of the Jordan member overlie the Lodi siltstone. The limited thickness of basal Jordan strata, including intercalated dolomitic shales, contains a closely packed succession of faunal units, each characterized by a distinct species of *Calvinella*. Thus there appears to have prevailed here, as in the case of the lithologically rather similar St. Lawrence member, a condition where factors favoring deposition were closely balanced by those favoring limited submarine erosion and/or nondeposition. Faunal units thus tend to be closely packed vertically and in lenses in areal distribution.

Along the Mississippi, the basal Jordan *Calvinella* beds are succeeded by siltstone strata similar lithologically to those of the Lodi member. These strata enclose fossils belonging to the *Saukiella pepinensis* faunal unit, and where the beds attain their greatest thickness, in Dakota County, Minnesota, the succeeding *Walcottaspis vanhornei* fauna as well. The siltstone grades eastward into unfossiliferous sandstone. The main body of the Jordan member above and lateral to the siltstones and conglomeratic dolomites just described consists of fine, friable, more or less dolomitic sandstones which Ulrich (1924) embraced in his term *Norwalk*. The higher Norwalk beds are sparingly fossiliferous and best characterized by *Saukiella frontalis* U & R.

The Jordan member was deeply eroded previous to the deposition of the Madison formation in central and southern Wisconsin; but along the Mississippi and in the lower Minnesota Valley the member is essentially its original thickness, with terminal sands ("Van Oser Beds," Stauffer, 1940) interpreted as a regressive phase of Jordan deposition (Raasch, 1939). Stauffer (1940) figures, but does not describe, a fauna from these beds.

SUNSET POINT FORMATION

At most places, south of a line through central Trempealeau County, an independent depositional cycle, dominantly sand with varied proportions of dolomite, intervenes between the Jordan member of the Trempealeau and the Ordovician Oneota formation. To this unit, the term Madison has been applied (ref. Raasch, 1935). Because pre-Madison erosion deeply truncated the Jordan member in central and southern Wisconsin, the Madison merits the status of an independent formation. However, the application of the term Madison to these strata has created much confusion, owing especially to the widespread use of the same name for a Mississippian limestone unit in Montana and Wyoming. The writer therefore proposes that, for the Cambrian unit, the term *Sunset Point* be substituted, after the bluff of that name at the Madison sandstone type locality.

The unit is locally fossiliferous, but the fauna has not been specifically described.

The Saukia Zone

Because many trilobite genera range through much of the Trempealeau and in fact back into the Bad Axe member of the Franconia and into the Madison (or Sunset Point) formation, this inclusive succession of faunal units is considered to represent a single faunal zone. The saukid genera, *Saukia, Saukiella, Tellerina,* and *Calvinella,* i.e. *Saukia* in the sense of Walcott's (1914) use of the term, together characterize this succession, but the later subdivision and restriction of the term *Saukia* by Ulrich and Resser leaves no single genus whose range coincides completely with the full time and rock span. Accordingly the writer proposes to apply the term *Saukia* to the succession involved, using that term in the broader sense of Walcott. Thus the biochron of the Saukinae coincides with the time span of the *Saukia* zone, except for the genus *Prosaukia,* which is ancestral to the other members of the subfamily and characterizes the *Prosaukia* subzone of the preceding *Ptychaspis-Prosaukia* zone.

REFERENCES

Miller, S. A., North American geology and paleontology, 1889.

Owen, D. D., Report of a geological survey of Wisconsin, Iowa, and Minnesota . . ., 1852.

Raasch, G. O., Stratigraphy of the Cambrian system of the Upper Mississippi Valley, Guidebook Ninth Annual Field Conference, Kansas Geol. Soc., 1935, pp. 302-315.

———, Cambrian Merostomata, Geol. Soc. Amer. Special Paper 19, 1939.

Stauffer, C. R., Fauna of the Van Oser beds, Jour. Paleontology, vol. 14, no. 1, 1940, pp. 54-56.

Ulrich, E. O., and C. E. Resser, The Cambrian of the Upper Mississippi Valley; Part I, Trilobita, Dikelocephalinae and Osceolinae, Milwaukee Public Museum Bull., vol. 12, no. 1, 1930.

Ulrich, E. O., and C. E. Resser, *idem.;* Part II, Trilobita, Saukinae. Milwaukee Public Museum Bull., vol. 12, no. 2, 1933.